

# **Tuning Control for Debutanizer Column**

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**Universiti Teknologi PETRONAS  
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# **CERTIFICATION OF APPROVAL**

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## **CERTIFICATION OF ORIGINALITY**

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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MUHAMMAD AIMAN AFIF BIN MUHAMMAD WAZIR

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## **ABSTRACT**

The performance of various conventional control strategies was compared against the self tuning Proportional Integral Derivative (PID) controller which examined when been applied in composition control of a debutanizer column. Tuning of PID control strategies studied and analyzed included Smith Predictor control, Internal Mode control, Cascade control, Feedback control and Feedforward-feedback control. The comparisons were done by MATLAB Simulation using Identification Tool (IDENT) and SIMULINK. The comparison for each control strategy performance was studied in terms of response towards set point changes and disturbance rejection towards error, manipulated variable which is valve opening and the scope. The success of control strategies are determined by the stability of the process model obtained from each control strategies.

# **CHAPTER 1: INTRODUCTION**

## **1.1 Background**

Yasuki et al (2008) stated that the PID controller is the most common form of feedback. It was an essential element of early governors and it became the standard tool when process control emerged in the 1940s. Its early implementation was in pneumatic devices, followed by vacuum and solid state analog electronics, before arriving at today's digital implementation of microprocessors. Jing (2001) claimed that in process control today, more than 97% of the control loops are of PID type, most loops are actually PI control. PID controllers are today found in all areas where control is used.

The controllers come in many different forms. There are standalone systems in boxes for one or a few loops, which are manufactured by the hundred thousand yearly. PID control is an important ingredient of a distributed control system. The controllers are also embedded in much special purpose control systems. PID control is often combined with logic, sequential functions, selectors, and simple function blocks to build the complicated automation systems used for energy production, transportation, and manufacturing. Many sophisticated control strategies, such as model predictive control, are also organized hierarchically. The ability of PID control mode to compensate most practical industrial process has led to their wide acceptance such as in pulp and paper industries (**Astrom 2002**).

## **1.2 Problem Statement**

Although PID controllers are the most widely used control mechanism in the world, they are also the most basic. Therefore, PID controllers are significantly limited in their capabilities, especially when complex processes are required to perform a task. PID controllers are only capable of measuring varying inputs and calculating the difference between them. Because of this, some subject specific industries must use larger and/or more expensive controllers. PID controllers, when used alone, can give poor performance when the PID loop gains must be reduced so that the control system does not overshoot,

oscillate or hunt about the control set point value. They also have difficulties in the presence of non-linearity may trade-off regulation versus response time, do not react to changing process behavior and have lag in responding to large disturbances.

### **1.3 Objective**

This study will be conducted to compare different advanced control strategies in tuning controller method in debutanizer column and select the best control strategy among them. The comparisons were done by MATLAB simulation to evaluate the performance of the controllers in terms of response towards set point changes and disturbance rejection, and also the opening valve which represented by Manipulated Variable.

### **1.4 Scope of Study**

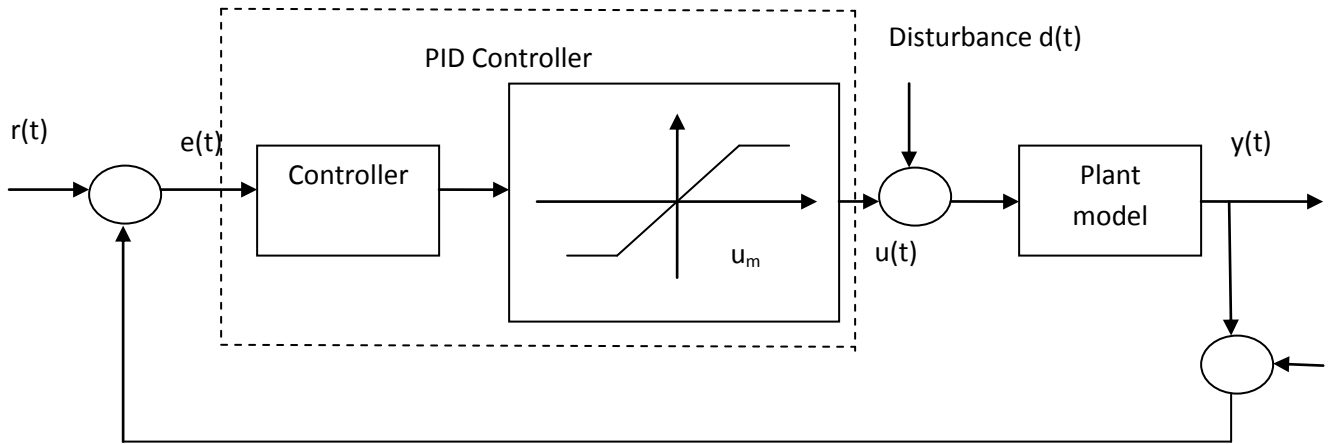
Performance of each control strategies for self tuning in debutanizer column will be studied and analyzed. The control strategies including Smith Predictor control, Internal Mode control, Cascade control, Feedback control and Feedforward-feedback control which will be tuned using Genetic Algorithm (GA). Different type of parameters will be applied to measure the performance of the control strategies including flow rate, level, temperature, pressure, error, manipulated variable which is valve opening and scope.

## **CHAPTER 2 : LITERATURE REVIEW AND THEORY**

### **2.1 PID Controller**

Hale (1995) stated that a proportional-integral-derivative controller (PID controller) is a control loop feedback mechanism widely used in industrial control systems. A PID controller calculates an error value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process through use of a manipulated variable.

A typical structure of a Proportional Integral Derivatives (PID) control system is:



**Figure 1: PID Structure**

PID Algorithm and mathematical description of PID controller:

$$U(t) = K \left[ e(t) + \frac{1}{T_i} \int_0^t e(\tau) d\tau + T_d \frac{de(t)}{dt} \right]$$

**(Astrom 2002)**

Where  $y$  is the measured process variable,  $r$  the reference variable,  $u$  is the control signal and  $e$  is the control error ( $e = y_{sp} - y$ ). The reference variable is often called the set point. The control signal is thus a sum of three terms: the P-term which is proportional to the error, the I-term which is proportional to the integral of the error, and the D-term

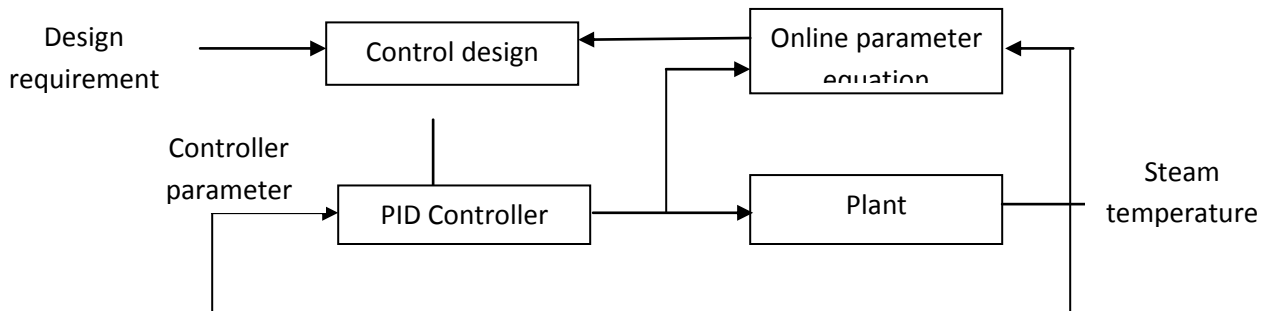


which is proportional to the derivative of the error. The controller parameters are proportional gain  $K$ , integral time  $T_i$ , and derivative time  $T_d$  (Astrom 2002).

## 2.2 Tuning of PID

Muzidah et al (2012) stated that conventional controller design methods will produce constant coefficient algorithms based upon an assumed linear time-invariant system. More systematic approaches has been studied and developed by applying various optimization techniques such as Genetic Algorithm, Particle Swarm Optimization, Bacterial Foraging Optimization and Stochastic Algorithms. The basis of a self tuning system is an algorithm that will automatically change its parameter to meet a particular requirement or situation. This is achieved by the addition of mechanism which monitors the system and adjusts the coefficient of the corresponding controller to maintain a required performance.

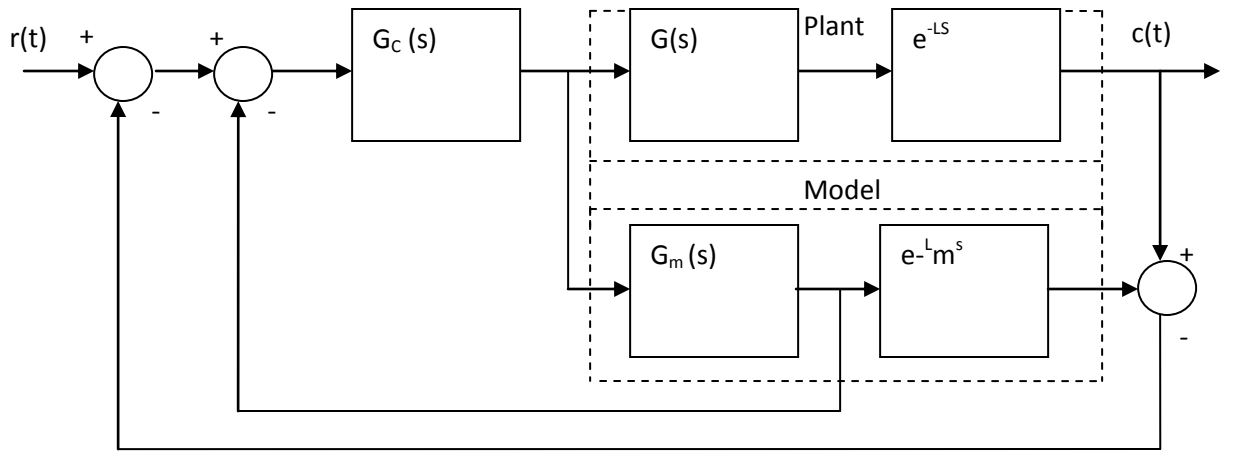
The ability to adapt with process variations such as load changes and disturbances has made self tuning PID an excellent alternative to the conventional method. Explicit self-tuning control (STC) use the information from model parameters that must be updated recursively in order to synthesized a new controller parameters based on specified design requirements. In some self-tuning controller, the recursive process estimation was not necessary. This type of controller is referred to as implicit self-tuning controller. Explicit STCs apply certainty equivalence principle where model uncertainties during parameter estimation were not considered. It is assumed that these values correspond to their actual values (Muzidah et al 2012).



**Figure 2: Explicit self tuning control structures**

### 2.3 Smith Predictor (Dead-time Compensation)

Processes that contain a large transport lag can be difficult to control because a disturbance in set point or load does not reach the output until unit of time elapsed. Dead time compensation or also known as Smith Predictor, attempts to reduce the deleterious effect of transport lag (Donald et al 2009). The Smith Predictor is a model based controller that is effective with long dead time which has inner loop with main controller that can be simply designed without the dead time (Hang 1994). The effects of load disturbance and modeling error are corrected through an outer loop and this predictor also can be used for processes with significant non minimum phase dynamics and for high order systems that exhibit apparent dead time.

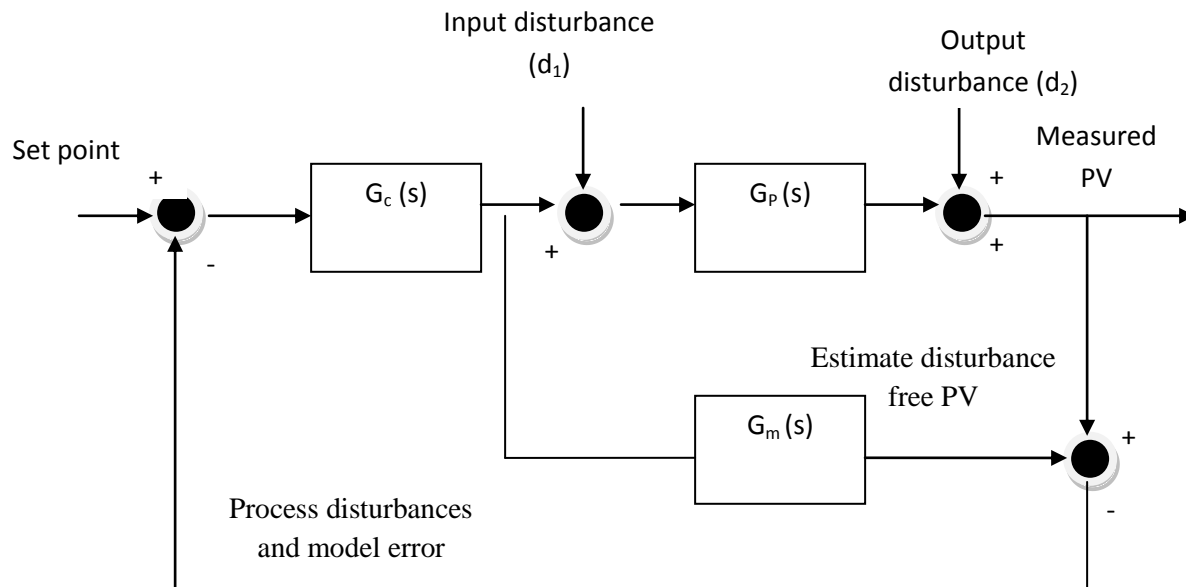


**Figure 3: Smith Predictor Control Scheme**

Smith Predictor as shown in Figure 4 is well known as effective dead-time compensator for a stable process with long time-delays. Ibrahim (2002) stated that while the Smith predictor structure provides a potential improvement in the closed loop performance over conventional controllers for stable processes, the structure cannot be used to control open loop unstable processes.

## 2.4 Internal Mode Control (IMC)

Donald et al (2009) stated that Internal Mode Control (IMC), which is based on an accurate model of the process, leads to the design of a control system that is stable and robust. A robust control system is one that maintains satisfactory control with changes in dynamics of the process (Donald et al 2009). Tien-li et al (2010) stated that Internal model-based control (IMC) has been shown to possess many advantages over PID control, particularly in the presence of significant process dead time. Implementation of IMC is simplified in a large class of industrial applications where the process dynamics can be adequately characterized by a simple first-order model requiring only estimates of process gain, lag time constant, and dead time for implementing the controller design (Tien-li et al 2010).



**Figure 4: Internal Model Control diagram**

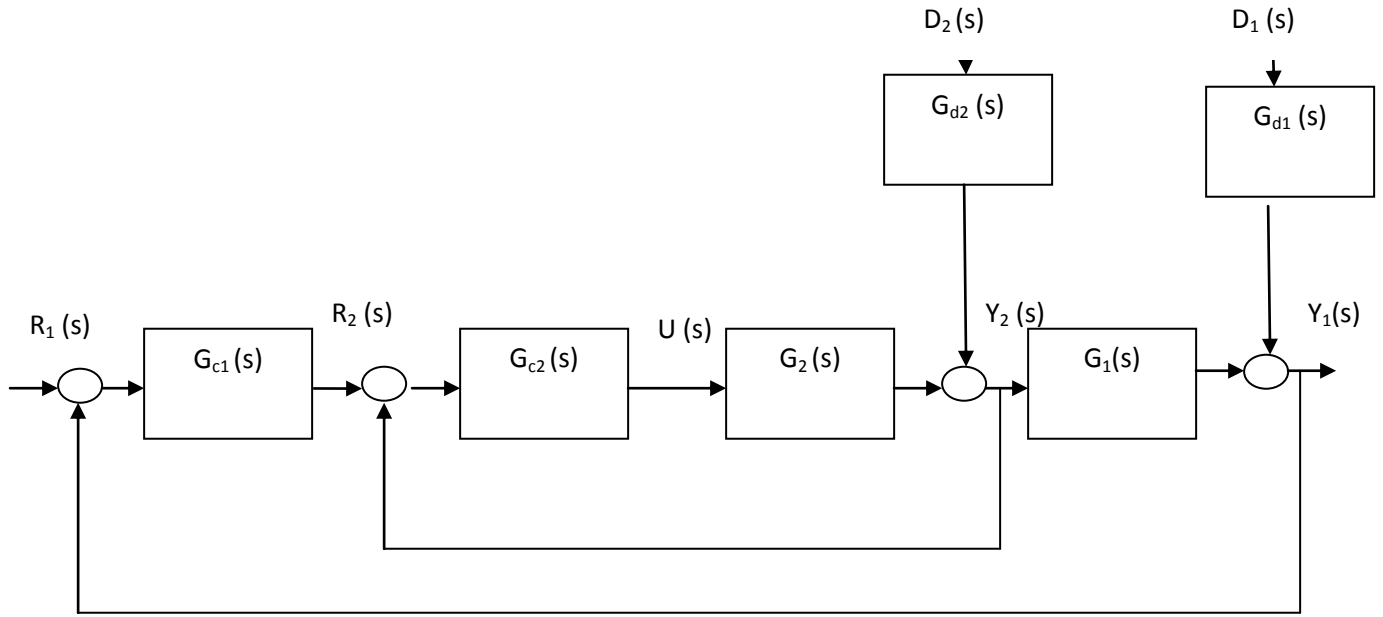
Donald (2002) proposed that in applying IMC control system design, the following information must be specified:

- Process model
- Model uncertainty
- Type of input (step, ramp)
- Performance objective (Integral square error, overshoot)

Based on Figure 5, for an IMC-based control system, an internal model of the process is built into the controller structure. The CO that is sent to the process is also used by the model to predict the future process output (PV). To simplify the design implementation, the mathematical model used is often a lower- order parametric model for example, a first-order model where only model gain, model lag time constants, and model dead time are needed. The difference between the measured PV and the model output signal represents an estimate of the overall system disturbances including not only the actual physical disturbances affecting the process but also the effects of model inaccuracies and measurement errors (Tien-li et al 2010).

## **2.5 Cascade Control**

Jeng et al (2012) stated that cascade control is one of the most successful control structures for enhancing single-loop\_control performance, and particularly when the disturbances are\_associated with the manipulated variable. Therefore, cascade control has been applied extensively in chemical process industries (Jyh 2014). The standard cascade control approach is to nest one feedback loop inside another feedback loop using two controllers. The controller of the inner loop is called the secondary controller, whereas the controller of the outer loop is the primary controller. The rationale behind this configuration is that the fast dynamics of the inner loop will enable faster disturbance attenuation and minimize the possible effect of the disturbances before they affect the primary output, which is the controlled variable of interest (Jeng et al 2012).



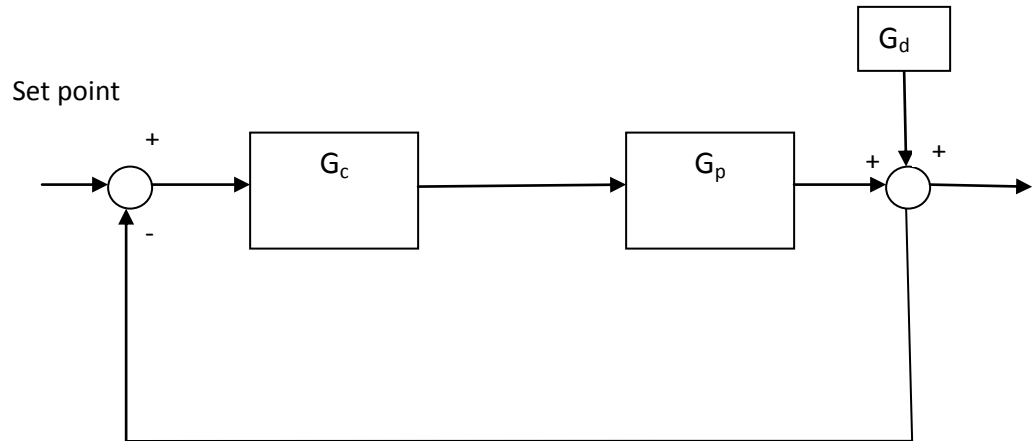
**Figure 5: Configuration of Typical Cascade Control System**

According to Jyh (2014), in a cascade control scheme, the introduction of an additional sensor creates a secondary (inner) loop that effectively attenuates disturbances. Figure 5 shows the configuration of a typical cascade control system, where  $G_1$  is the primary process and  $G_2$  is the secondary process. The primary controller  $G_{c1}$  uses the primary process variable  $y_1$  with set-point  $r_1$  to establish the set point  $r_2$  for the secondary controller  $G_{c2}$ . The secondary process variable  $y_2$  is transmitted to the secondary controller, which adjusts the manipulated variable  $u$ . Disturbances can enter at two possible points,  $d_1$  and  $d_2$ , with disturbance transfer functions  $G_{d1}$  and  $G_{d2}$ , respectively. A cascade control scheme is effective because the disturbance  $d_2$  affecting the inner loop is promptly compensated before it affects the primary process variable  $y_1$ .

## 2.6 Feedback and Feedforward-feedback Control System

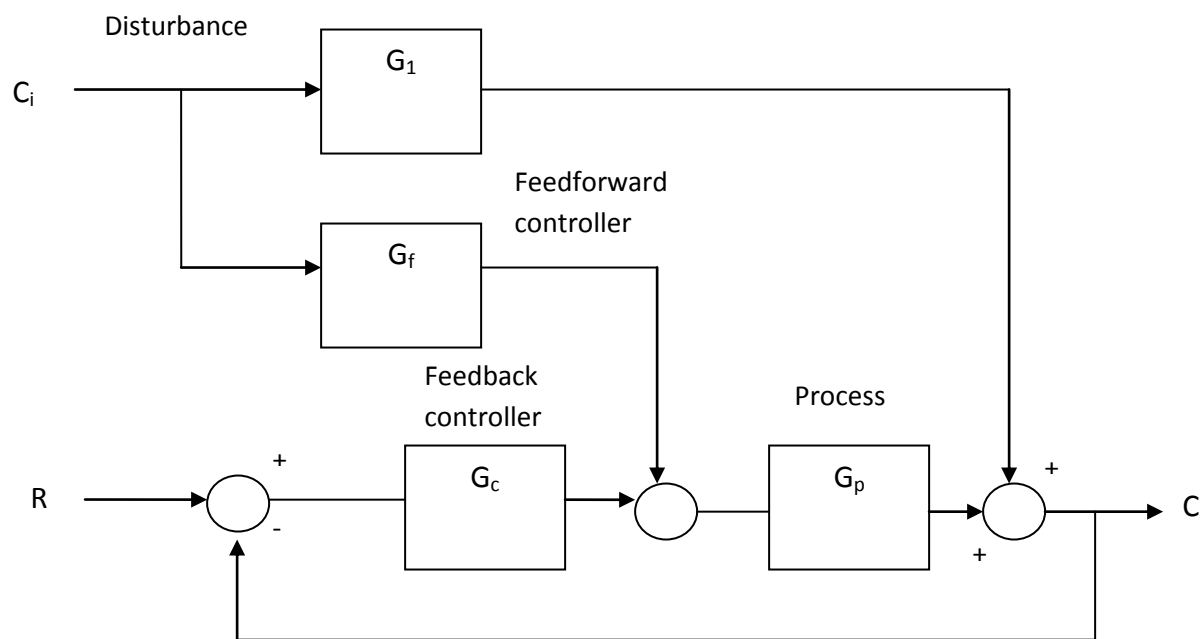
According to Donald et al (2009), feedback control is control strategy when the manipulated variable is adjusted based on the measurement of the controlled variable (CV). It is important to make a distinction between negative feedback and positive feedback. Advantages of using feedback control strategy are corrective action is taken

regardless of the source of the disturbances and it reduces sensitivity of the controlled variable to disturbances and changes in the process. Besides, it is simple to implement and also requires minimal detailed information about how the process itself works. Feedback control action is entirely empirical thus as long as an adjustment is being made in the correct sense then the control system should remove the effect of an external disturbance.



**Figure 6: Feedback Control Loop**

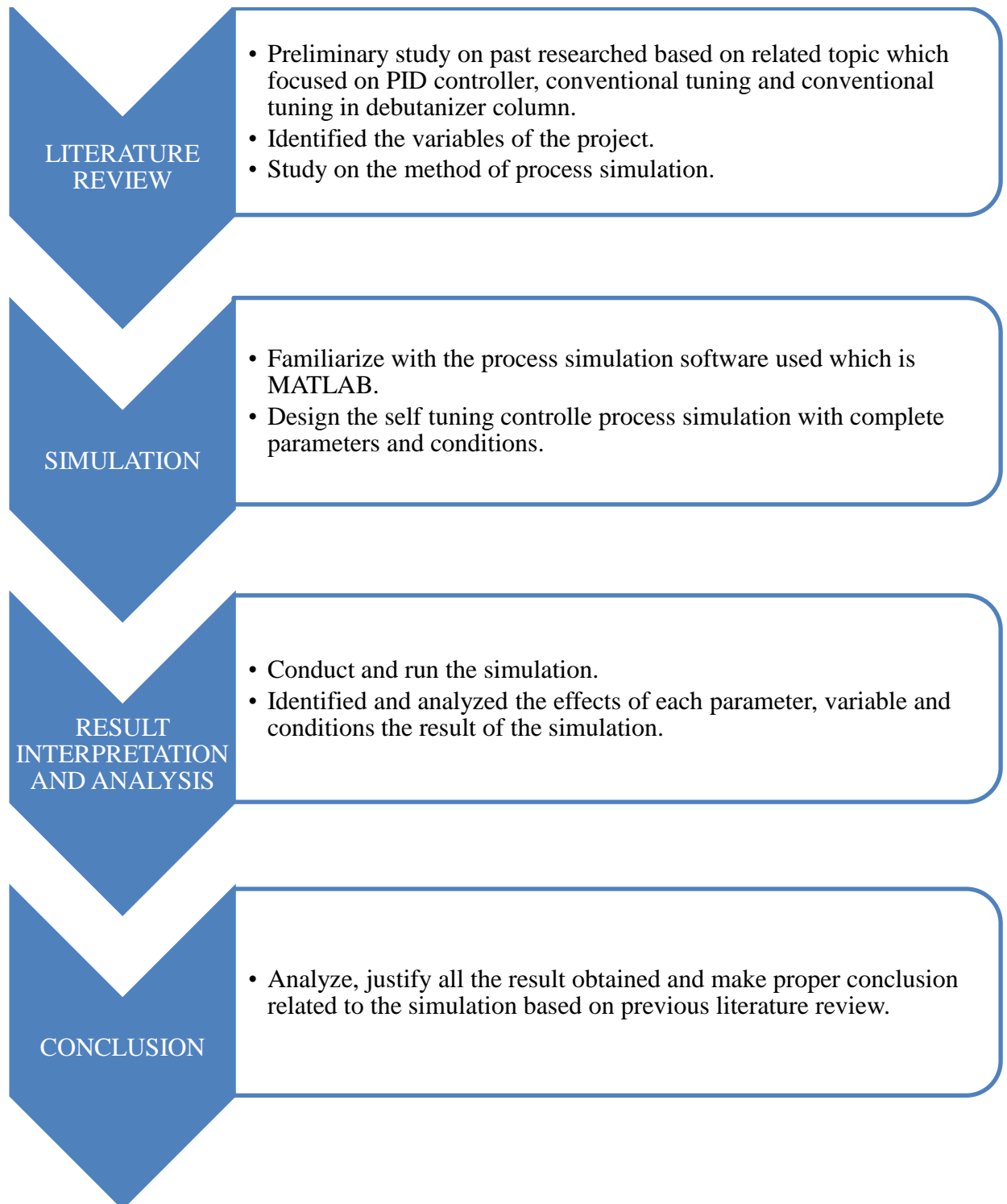
Donald et al (2009) also stated that feedforward control strategy is control strategy where the manipulated variable is adjusted based on the measurement of the disturbance variable (DV). In some cases the major load disturbance to a process may be measured and utilized to provide feedforward control. Advantages of using feedforward control strategy are it takes corrective action before the process is upset and does not affect system stability. The disadvantages of this control strategy are disturbance must be measured for example capital and operating costs, and requires more knowledge of the process to be controlled. Feedforward control is usually used in conjunction with feedback control to improve disturbance rejection. The strategy control called Feedforward-feedback control.



**Figure 7: Feedforward-feedback Control Loop**

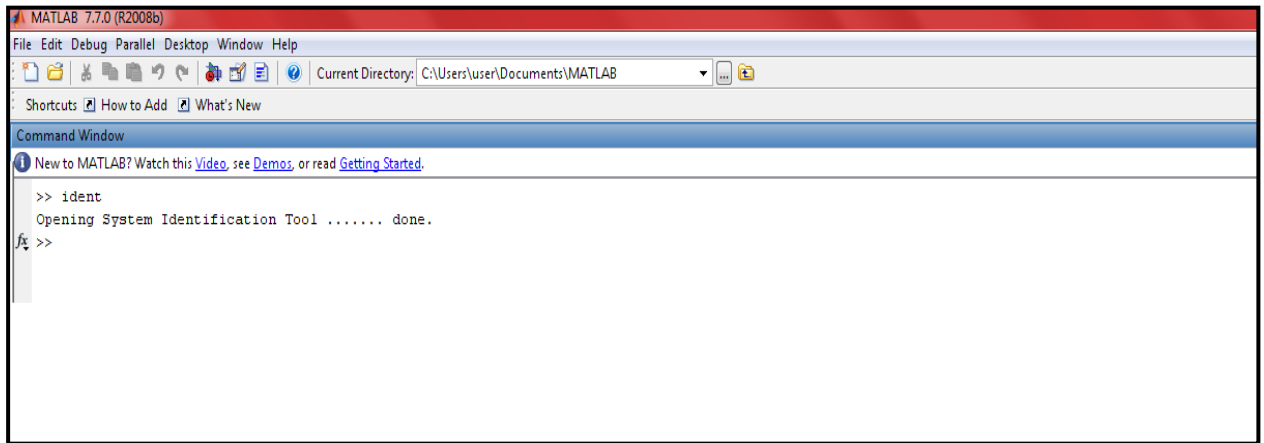
## **CHAPTER 3: METHODOLOGY**

### **3.1 Project Flow Chart**



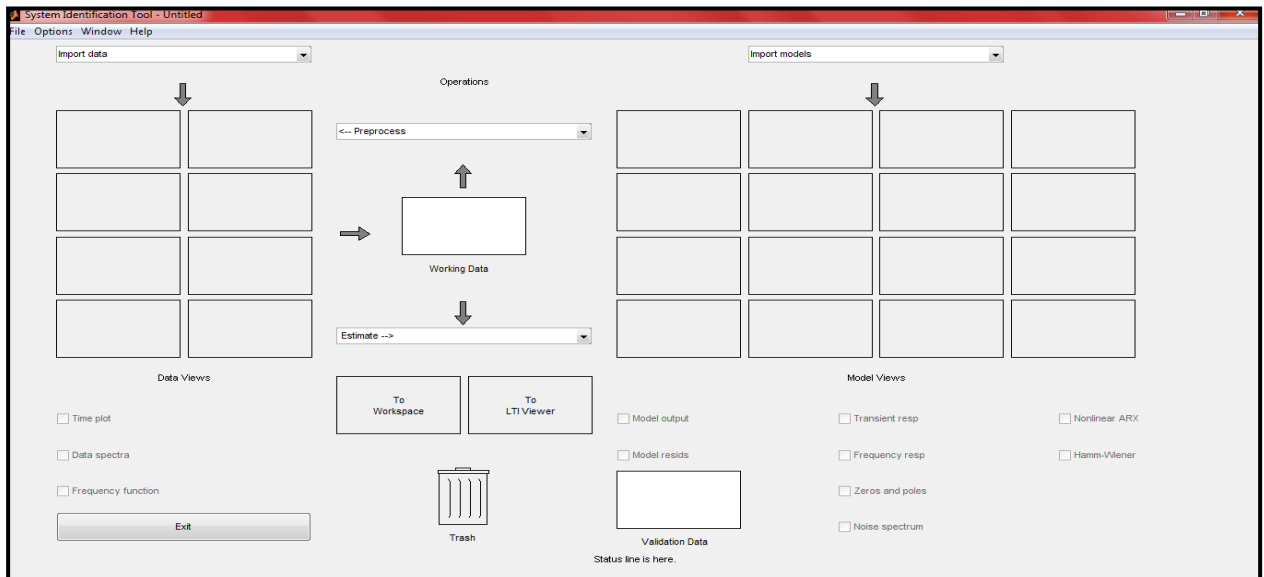


### 3.2 Project Methodology (MATLAB Simulation)



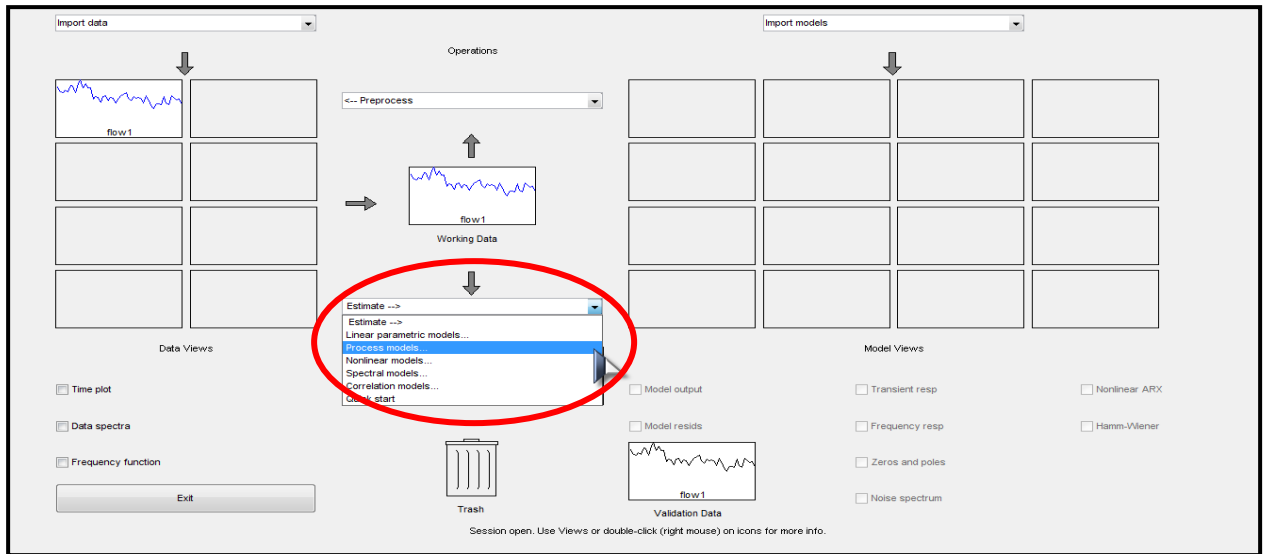
**Figure 8: MATLAB Interface**

MATLAB Simulation was used to study each control strategy performance in terms of set point regulation, response towards set point changes and disturbance rejection. After MATLAB program has been opened, in the command window, IDENT this stands for Identification Tools opened.



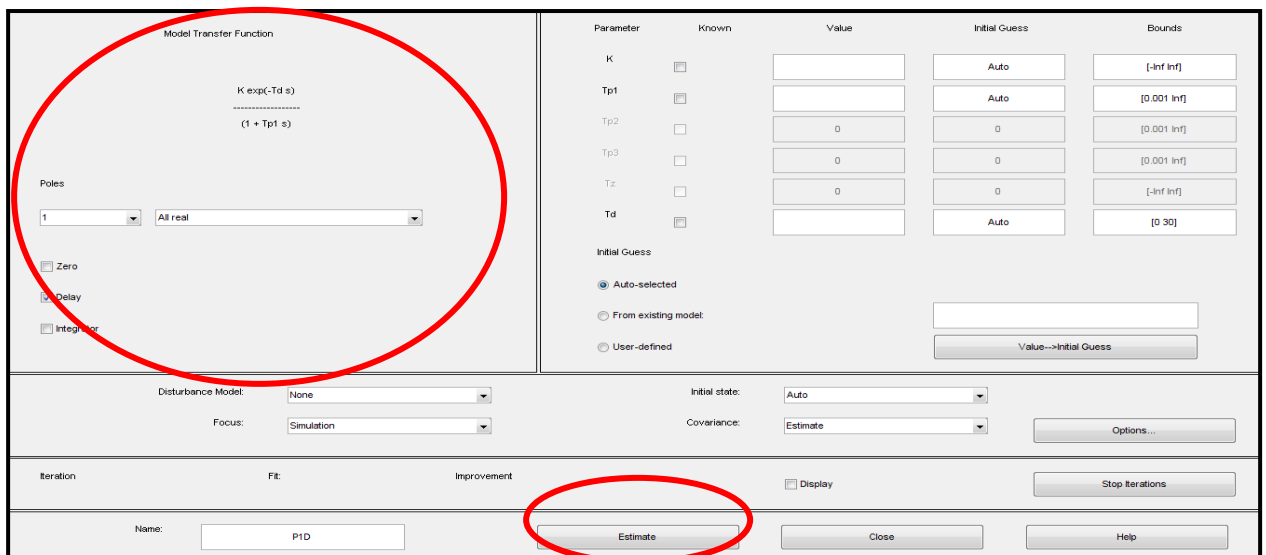
**Figure 9: IDENT Interface**

This is the main interface in System Identification Tools which will be used in determining the most stable and high performance of process models for each parameter including flow rate, level, pressure and temperature.



**Figure 10: Process Models Selection**

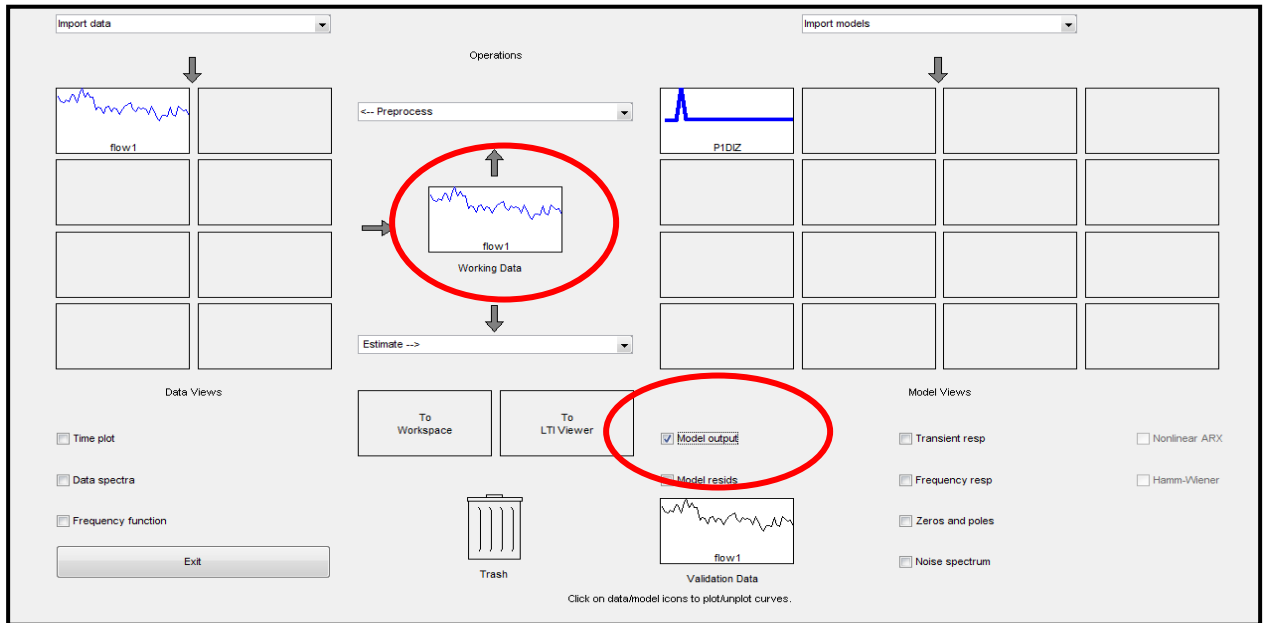
In IDENTt, as showed at Figure 10, at Estimate options, Process Models was chose in order to determine the best process model for each control strategies.



**Figure 11: Estimation of Transfer Function**

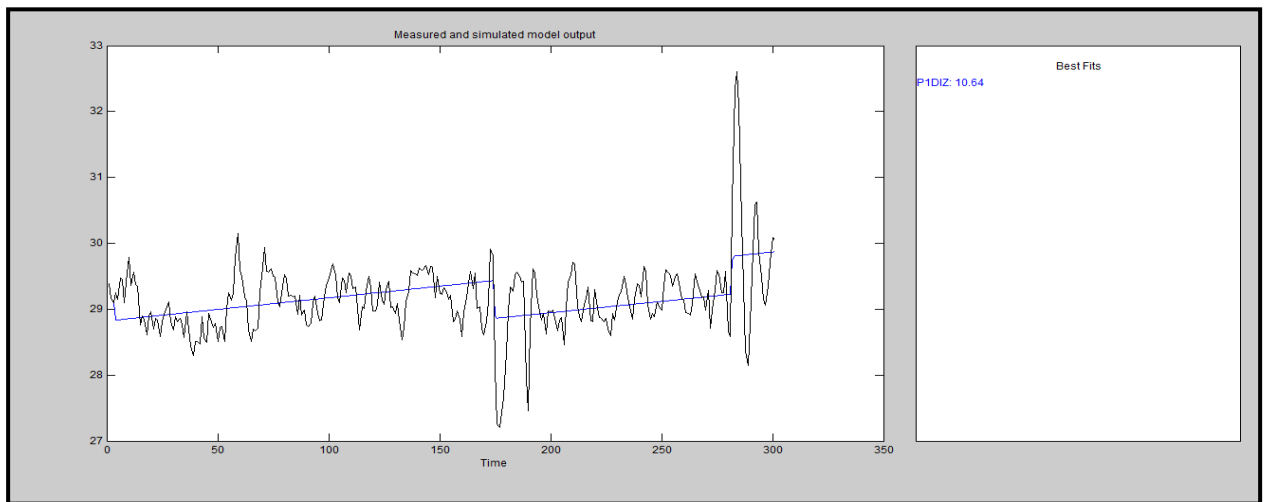
After Process Models has been chosen, this is the main interface of Process Models criteria selection. In this interface, there are stated Main Transfer Function and Poles options. In Poles options, number of poles has to be selected and confirmed which range

from 0 to 3 and also have to choose between All Real and Under damped properties. Next, for Poles properties, we have to choose between Zero order, Delay and Integrator. Next, Estimate option is choose.



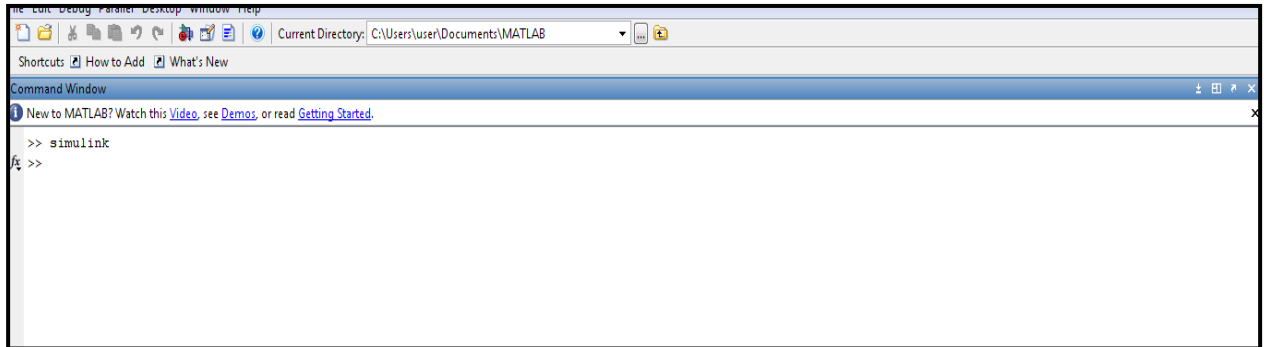
**Figure 12: Selection of Most Stable Transfer Function**

As we can see from Figure 12, the process model already been developed, which showed in Working Data. To get the full result of stability and performance of the process model that has been generated, Model Output option is selected.



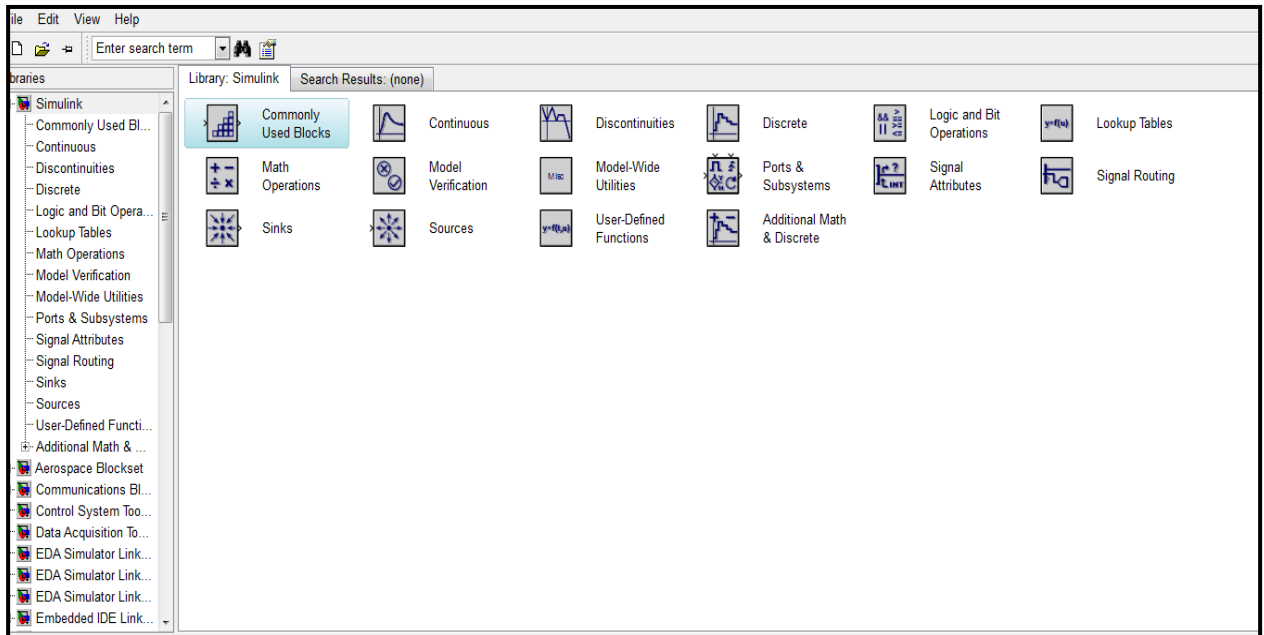
**Figure 13: Value of Selected Process Models**

Figure 13 showed that the value for the process models obtained is 10.64. The best and high performance of process models will be approaching positive 100. These steps were repeated until the highest value of all process models examined is obtained.



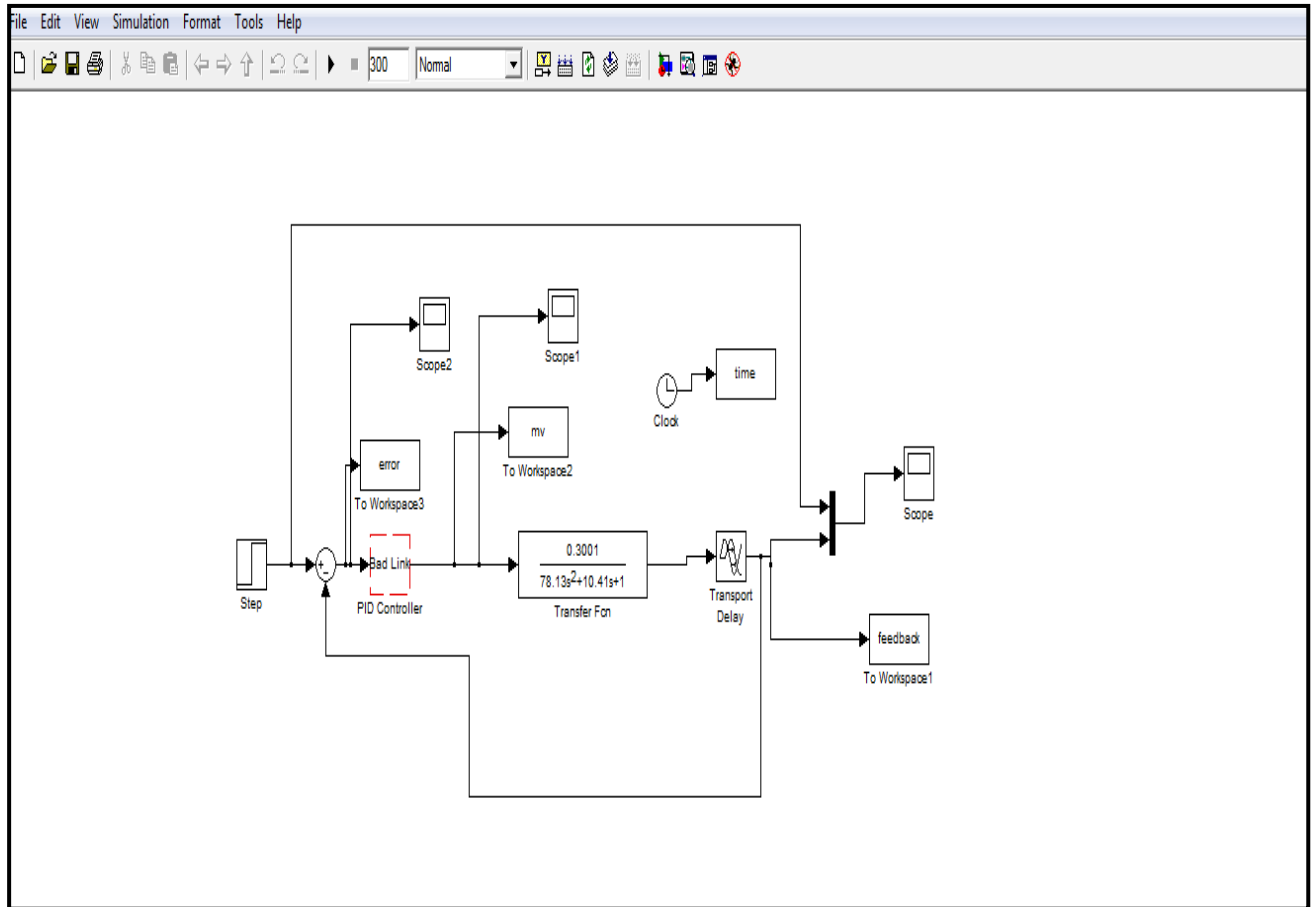
**Figure 14: SIMULINK Interface**

After the best process model is obtained from simulation of IDENT, SIMULINK was used to determine the best self tuning control strategy using the process models obtained. As can be seen in Figure 14, in the command window, SIMULINK function was inserted and opened.



**Figure 15: Startup of Block Diagram in SIMULINK**

This is the main interface of Simulink function. In this section, block diagram of different control strategy will be developed to determine the most efficient and high performance in terms response towards set point changes and disturbance rejection.



**Figure 16: Example of Block Diagram**

This is one of the examples of block diagram generated from process models obtained. In **Figure 16**, the block diagram been developed is for **Feedback Control strategies**. Thus, this step will be repeated for all stated control strategies which included Smith Predictor control, Internal Mode control, Cascade control, and feedforward-feedback control.

### 3.3 Gantt Chart and Key Milestone

No	Detail Work	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Work continue.														
2	Simulation of Stability of Transfer Function														
3	Selection of suitable Transfer Function For Each Parameter														
4	Developing block diagram in SIMULINK.														
5	Analyze and investigated the effect of step input and disturbance input towards the result.														
6	Submission of Progress Report														
7	Project Work Continues														
8	Analyze the result which covered error,														

	manipulated variable (MV) and scope.													
9	<b>Pre-SEDEX</b>													
10	Submission of Draft Report													
11	Submission of Dissertation (soft bound)													
12	Submission of technical paper													
13	Oral Presentation													
14	Submission of Project Dissertation (Hard Bound)													

## CHAPTER 4: RESULTS AND DISCUSSION

	m3/hr		%		KPa	°C
CONTROLLERS	FLOW 1	FLOW 2	LEVEL 1	LEVEL 2	PRESSURE 1	TEMP 5
TAG NUMBER	FIC 123	FIC 126	LC 111	LC 112	PC 109	TC 110
PB	100	200	45	250	50	135.7
Kc	1.00	0.50	2.22	0.40	2.00	0.74
Ti (seconds)	30	12	660	550	42	250
Td (seconds)	0	0	0	0	0	80
Set Point, SP (m3/hr)	44.64	7.55	-	-	-	-
Set Point, SP (%)	-	-	45.88	7.6	-	-
Set Point, SP (KPa)	-	-	-	-	823.8	-
Set Point, SP (°C)	-	-	-	-	-	20

**Table 1: Parameters involved for simulation**

Using Identification Tools (IDENT) in MATHLAB, stable transfer function have been selected for each parameter considering the highest valued obtained approaching 100 units value.

### 4.1 Simulation of stability of Transfer Function

PARAMETER	TRANSFER FUNCTION
<b>FLOW 1</b>	$G(s) = \frac{46.28s + 3.676}{9.255s^3 + 5.281s^2 + 3.962s + 1}$
<b>FLOW 2</b>	$G(s) = \frac{-51.48s + 0.8559}{272.26s^2 + 3.679s + 1}$
<b>LEVEL 1</b>	$G(s) = \frac{0.00284}{0.8332s^4 + 1764s^3 + 100s^2 + 3.962s + s}$
<b>LEVEL 2</b>	$G(s) = \frac{-7.158s - 4323}{8.937s^2 + 1.44s + 1}$
<b>PRESSURE 1</b>	$G(s) = \frac{5105s + 107.4}{75.95s^2 + 49.3s + 1}$
<b>TEMEPERATURE 5</b>	$G(s) = \frac{1.381s + 13.89}{348.8s^2 + 137s + 1}$

**Table 2: Selected Transfer Function**

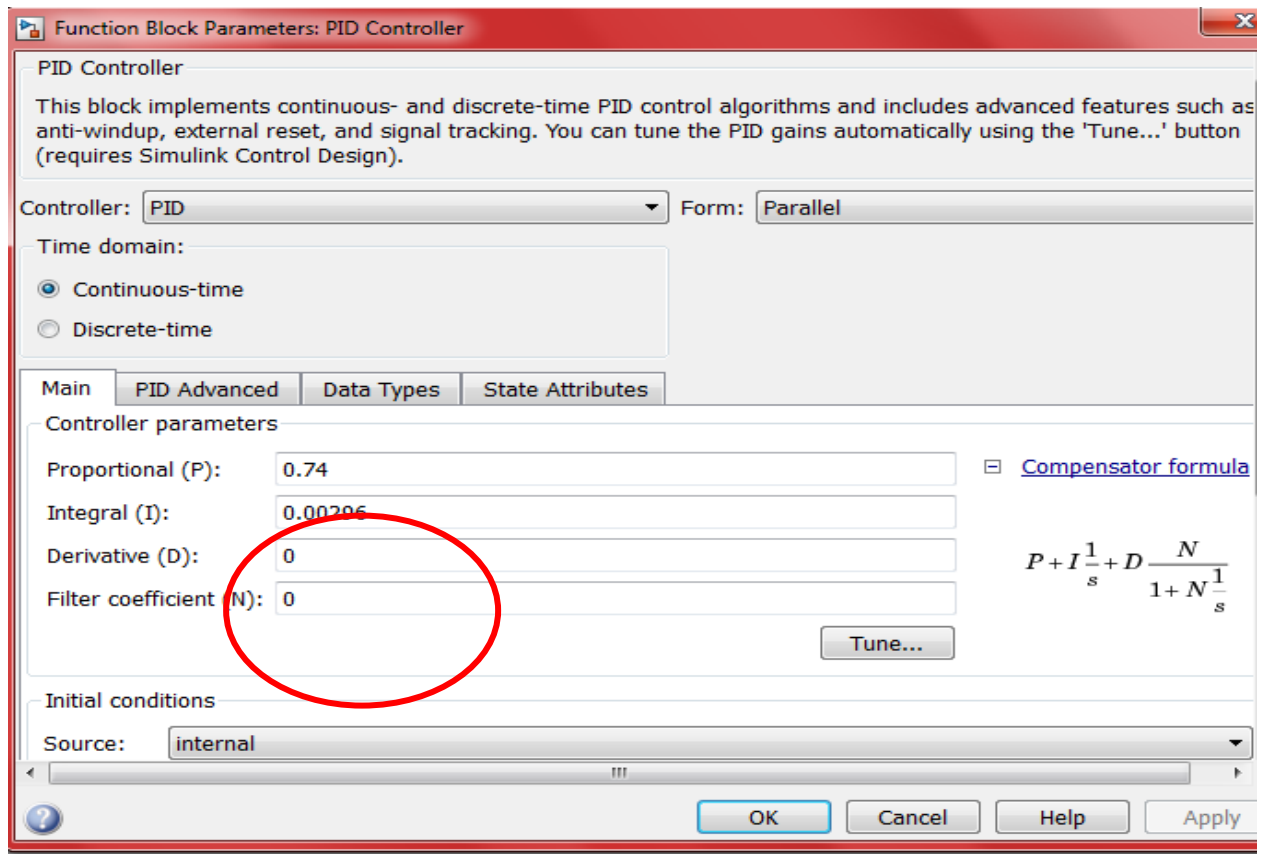


## 4.2 Simulation of Block Diagram in SIMULINK for Selected Transfer Function

In the simulation, the configuration for each PID controller for each parameter is varied as showed below, referring to the  $K_C$  value,  $T_i$  valued and  $T_d$  value.

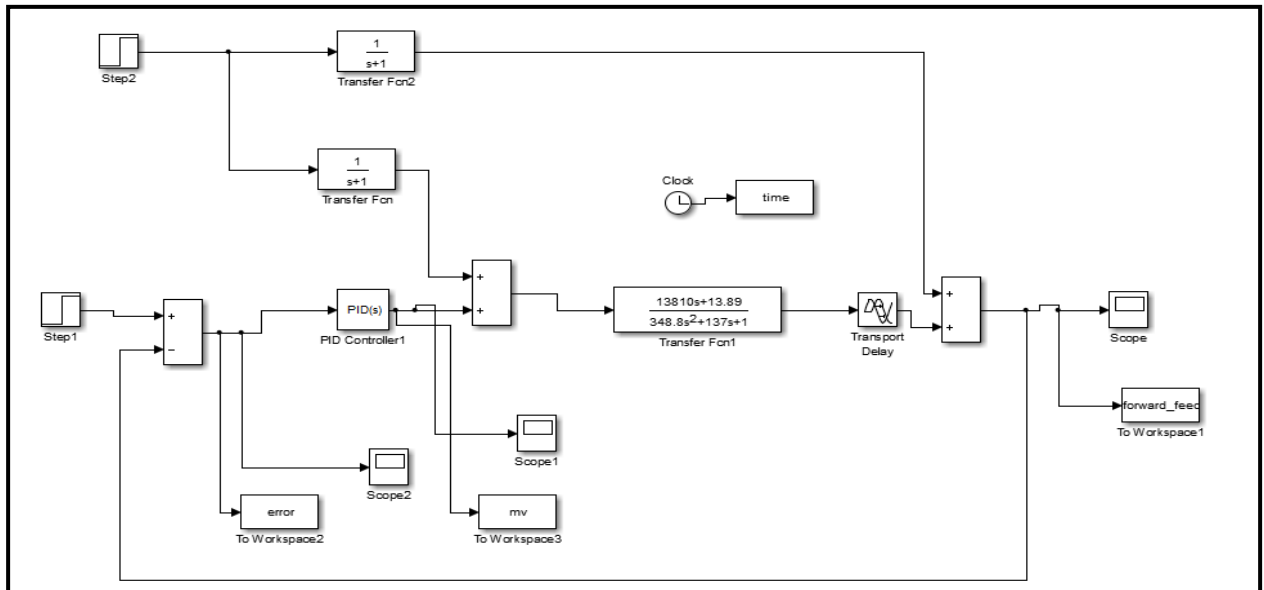
CONTROLLERS	FLOW 1	FLOW 2	LEVEL 1	LEVEL 2	PRESSURE 1	TEMP5
<b>K<sub>c</sub></b>	1.00	0.50	2.22	0.40	2.00	0.74
<b>T<sub>i</sub> (seconds)</b>	30	12	660	550	42	250
<b>T<sub>d</sub> (seconds)</b>	0	0	0	0	0	80

**Table 3: Configuration for PID Controller**



**Figure 17: Interface for Configuration for PID Controller**

### 4.2.2 Feedforward feedback Control Strategy



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### 4.2.3 Smith Control Strategy

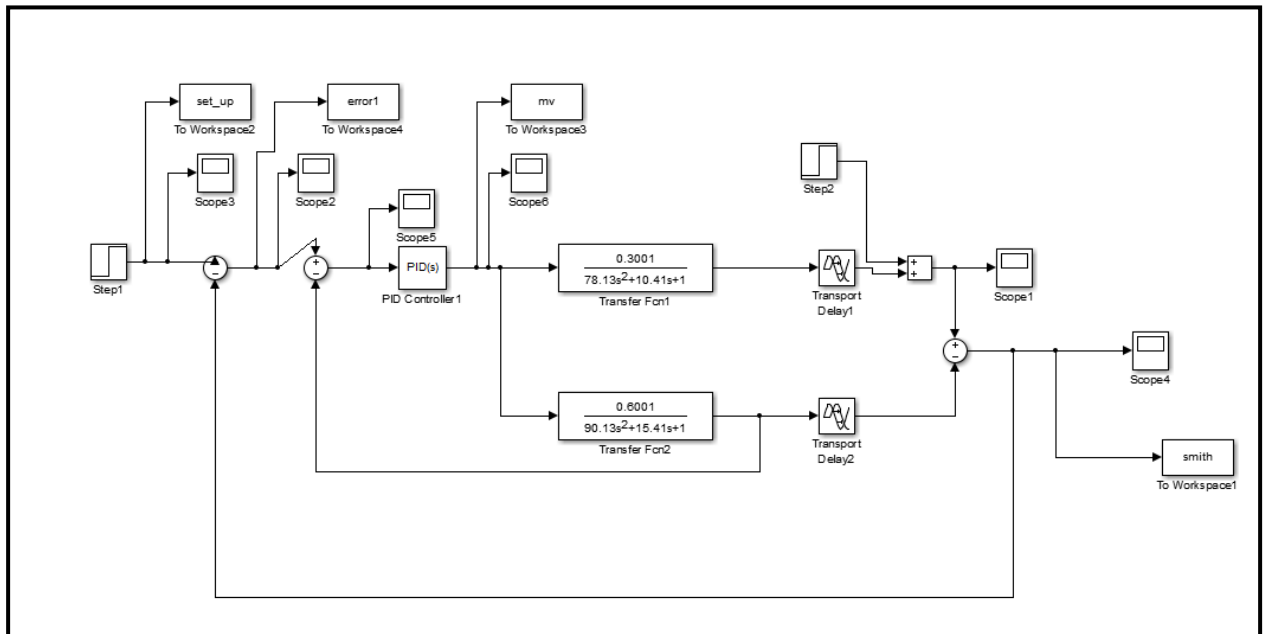


Figure 20: Step and Disturbance Input Simulation for Smith Control Strategy

### 4.2.4 Cascade Control Strategy

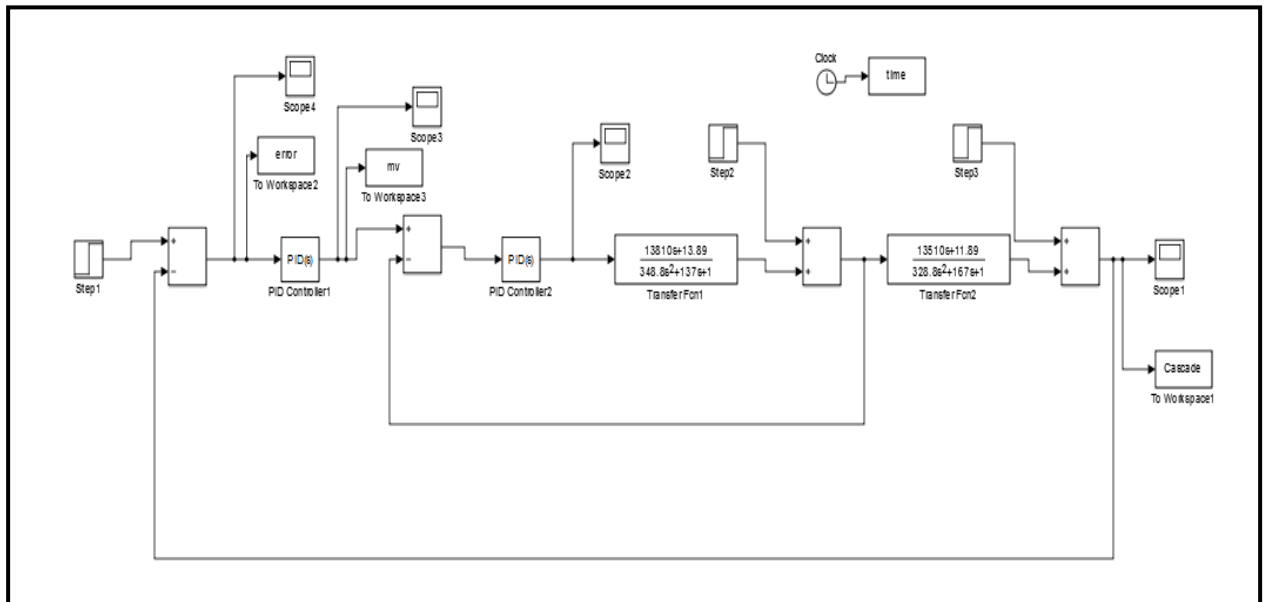
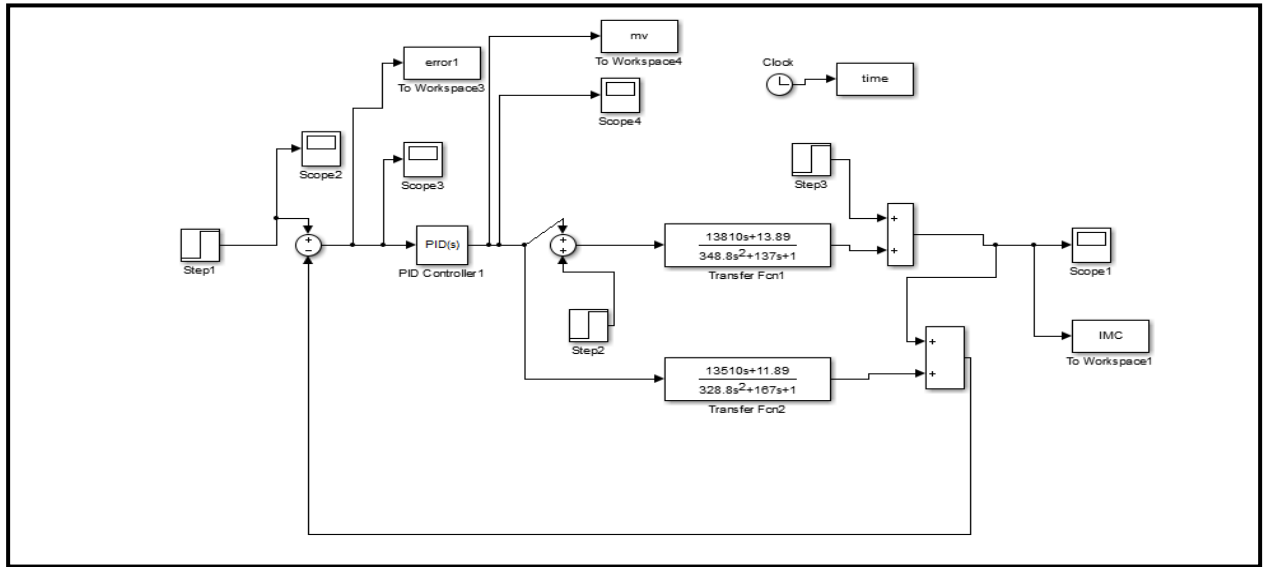


Figure 21: Step and Disturbance Input Simulation for Cascade Control Strategy

#### 4.2.5 Internal Mode Control (IMC) Control Strategy



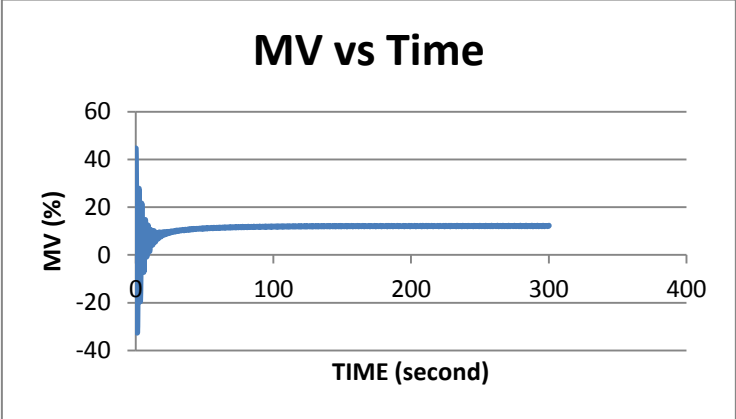
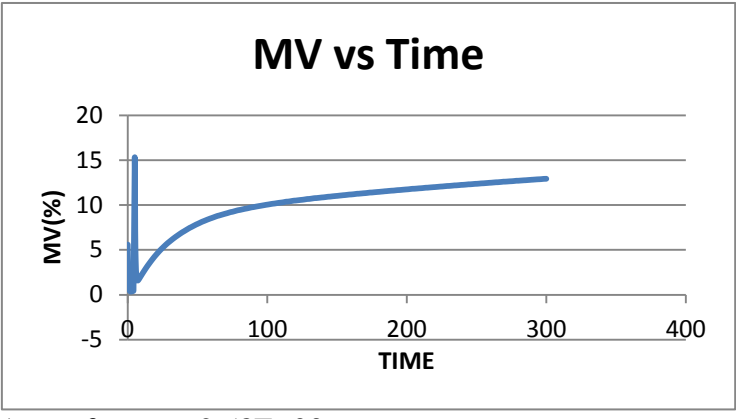
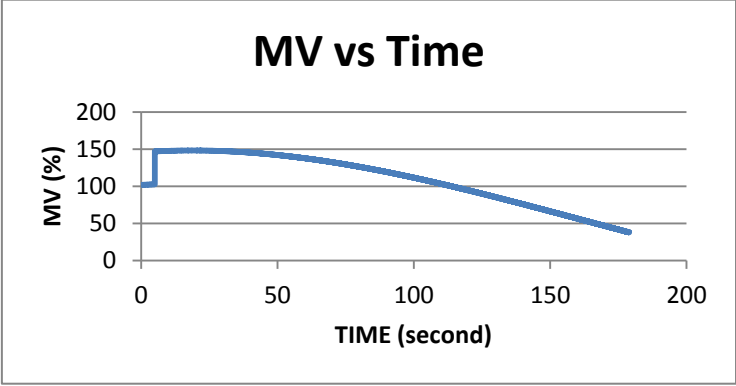
**Figure 22: Step and Disturbance Input Simulation for IMC Control Strategy**

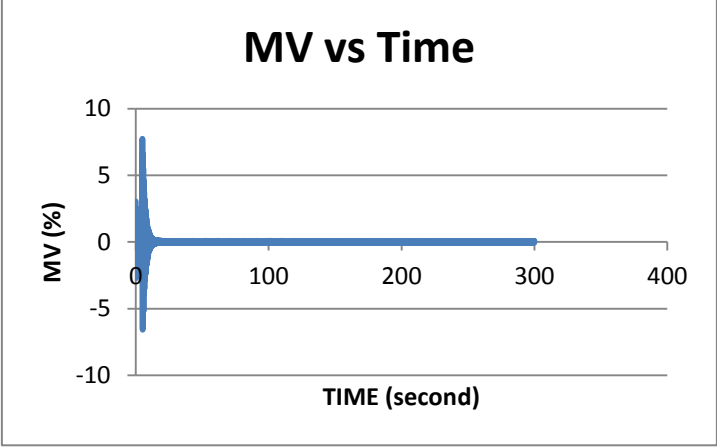
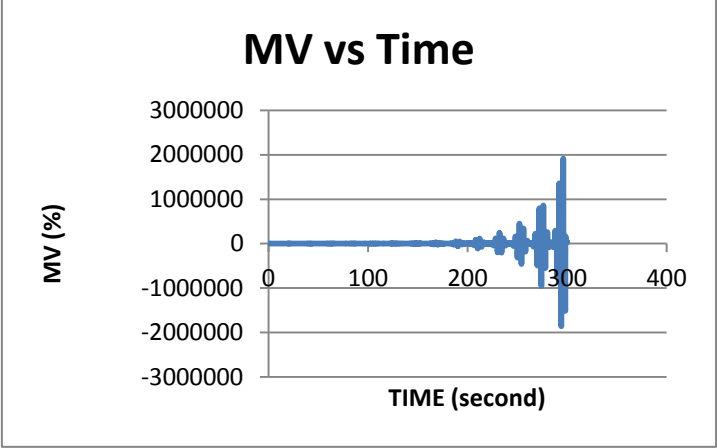
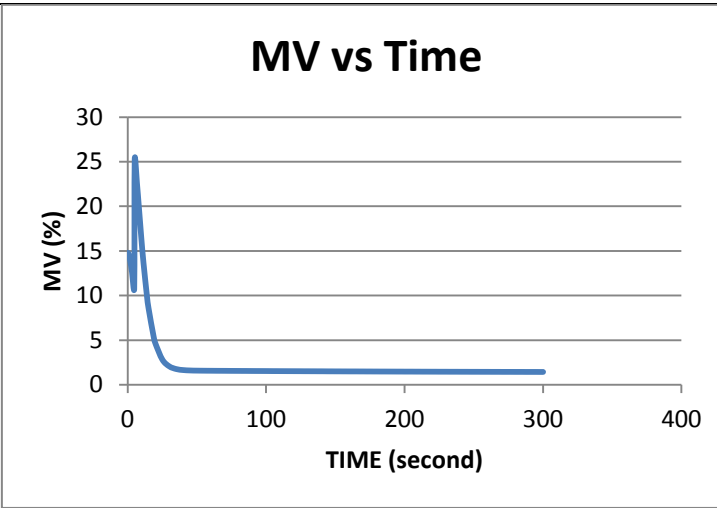
### 4.3 RESULTS AND DISCUSSION FOR SIMULATION IN SIMULINK

In determining and selecting the best controller for each parameter, there are 3 main criteria to be considered. The first criteria is the valve opening which represented by Manipulated Variable (MV) graph. For the best and stable condition in MV vs. Time graph, the valued should be in a range of 0 to 100, and the value also should not fluctuated much as it will reduces the performance of the valve. The next criteria are the area of error, represented by Error vs. Time graph. In the block diagram developed, error is measure before controller take place, so the value of area of error should as small as possible. The last criteria is scope which represent the overall performance of the parameter itself, which represented by Scope vs. Time graph.

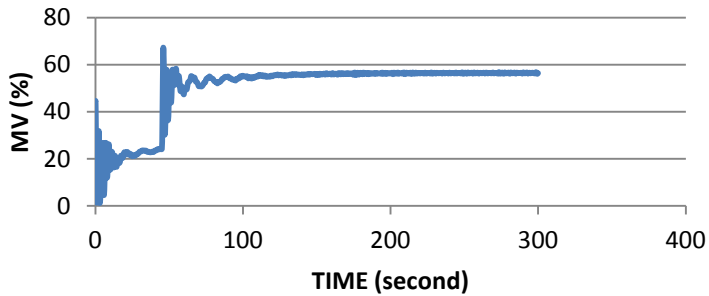
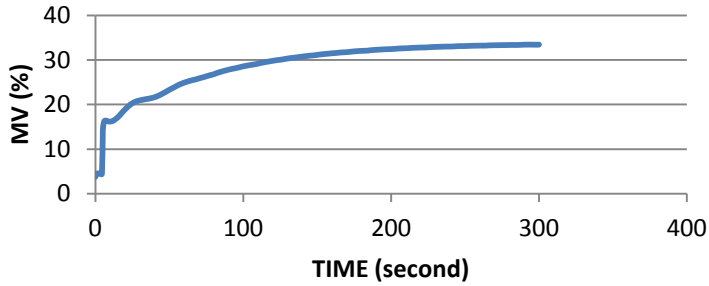
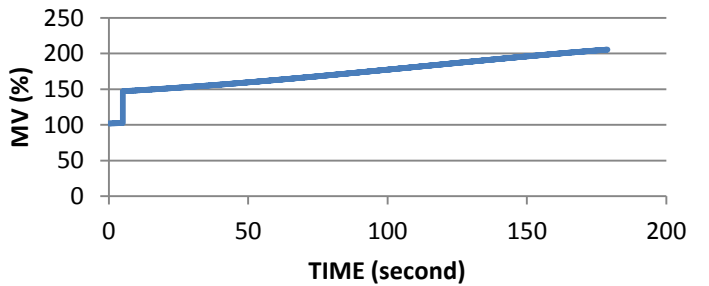
The simulation was conducted in 2 modes which the first one is in Step, where only Step 1 has the value for set point which Step 2 and Step 3 are 0. For second mode which is Disturbance, the situation is different where Step 2 and Step 3 have the value for set point, while for Step 1 the value is zero All the simulation for each control strategies for each parameter using selected stable transfer function has been successfully conducted. The full result for each control strategy is in Chapter 7 which is in appendices section.

#### 4.3.1 Best Control Strategy for Step

PARAMETER	CONTROL STRATEGY	DESCRIPTION
FLOW1	Internal Mode Control	 <p>Area of error = 367.392 Value fluctuated at the beginning and then maintained stable until the end of process.</p>
FLOW2	Internal Mode Control	 <p>Area of error = 2.58E+03 Value fluctuated at the beginning and then maintained stable until the end of process.</p>
LEVEL1	Internal Mode Control	 <p>Area of error = 5.52E+03 Stable</p>

LEVEL2	Internal Mode Control	 <p>Area of error = 2.8824 Fluctuating at the beginning and then maintained stable.</p>
PRESSURE1	Smith Predictor Control	 <p>Area of error = 2.8824 Stable</p>
TEMP5	Internal Mode Control	 <p>Area of error = 458.01 Fluctuating at the beginning and then maintained stable.</p>

#### 4.3.2 Best Control Strategy for Disturbance

PARAMETER	CONTROL STRATEGY	DESCRIPTION
FLOW1	Internal Mode Control	<p><b>MV vs Time</b></p>  <p>Area of error = <math>1.71E+03</math> Fluctuating at the beginning and then maintained stable until the end of process.</p>
FLOW2	Internal Mode Control	<p><b>MV vs Time</b></p>  <p>Area of error = 97.865 Fluctuating at the beginning and then maintained stable until the end of process.</p>
LEVEL1	Cascade Control	<p><b>MV vs Time</b></p>  <p>Area of error = <math>5.52E+03</math></p>

		Stable
LEVEL2	Internal Mode Control	<div data-bbox="704 226 1435 737"> </div> <p>Area of error = 1.03E+04 Fluctuating at the beginning and then maintained stable.</p>
PRESSURE1	Smith Predictor Control	<div data-bbox="704 814 1435 1262"> </div> <p>Area of error = 10241.79 Fluctuating and stable at positive value.</p>
TEMP5	Internal Mode Control	<div data-bbox="704 1360 1435 1787"> </div> <p>Area of error = 5753 Stable.</p>



## **CHAPTER 5: CONCLUSION**

This simulation project has successfully achieved the main objective which is to compare different advanced control strategies used in tuning controller method in debutanizer column and select the best advance control among them. The comparisons has been successfully conducted using MATLAB simulation to evaluate the performance of the controllers in terms of response towards set point changes and disturbance rejection, and also the opening valve which represented by Manipulated Variable. Internal Mode Control (IMC) control strategy has been selected as the best control strategy for both Step and Disturbance mode, considered the stability and minimum value of error obtained after the complete simulation. For further action plans, more parameter and other control of strategy should be consider and study to increase the efficiency for control strategy in debutanizer column.

## **CHAPTER 6: REFERENCES**

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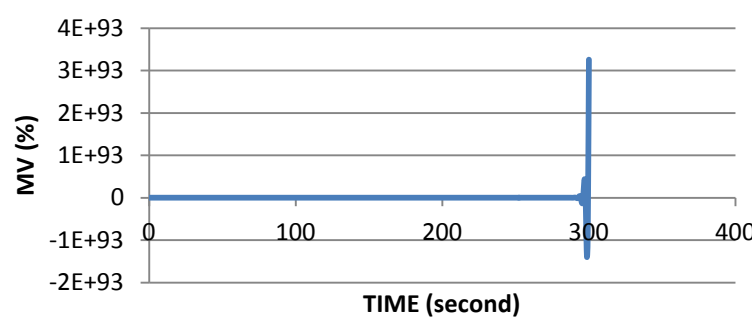
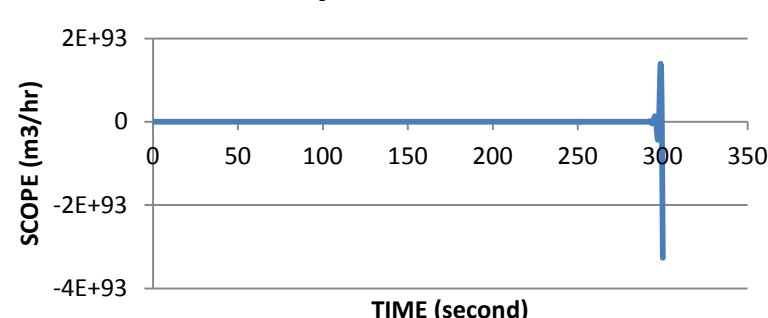
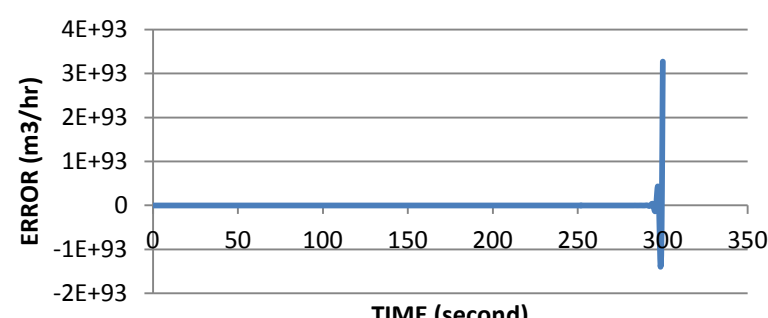
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# CHAPTER 7: APPENDICES

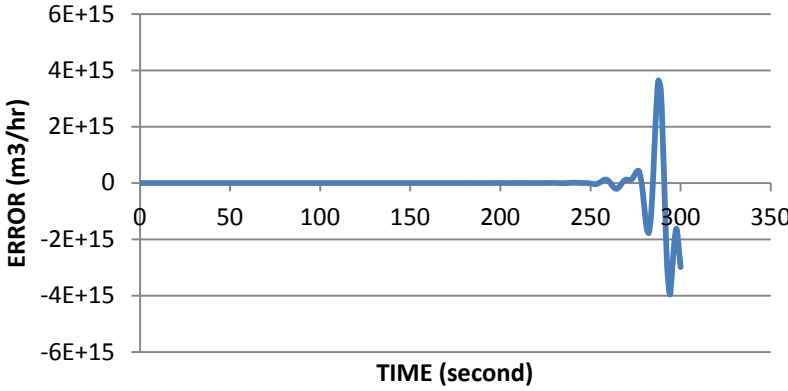
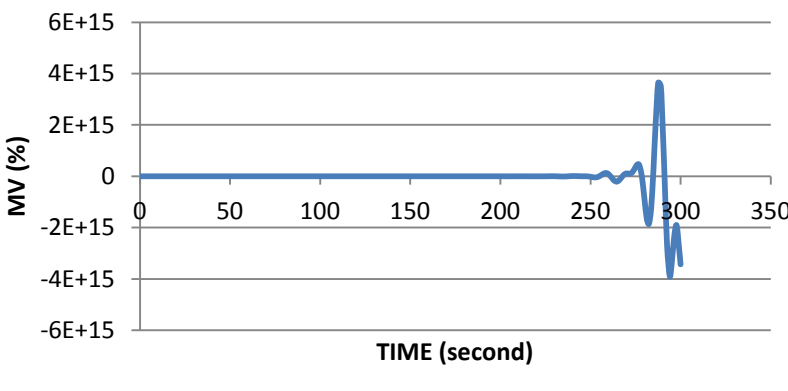
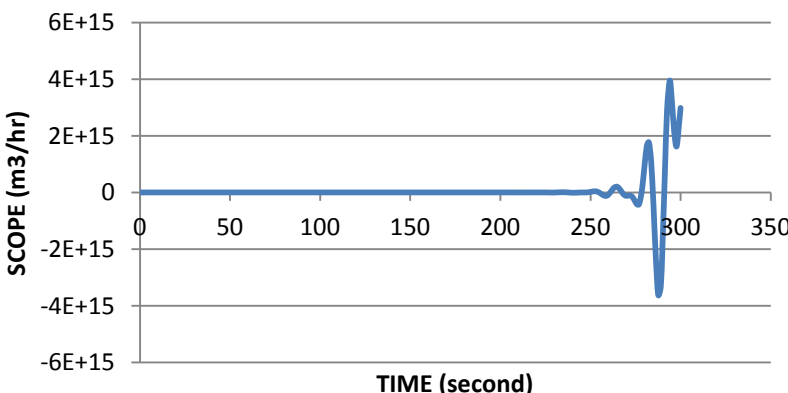
## 7.1 Disturbance

### 7.1.1 FLOW1

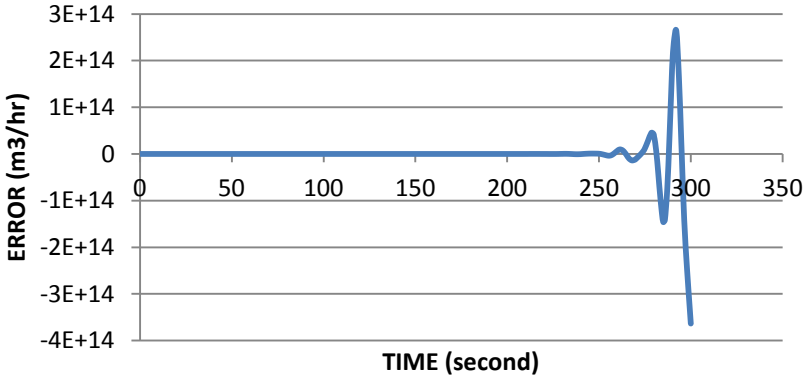
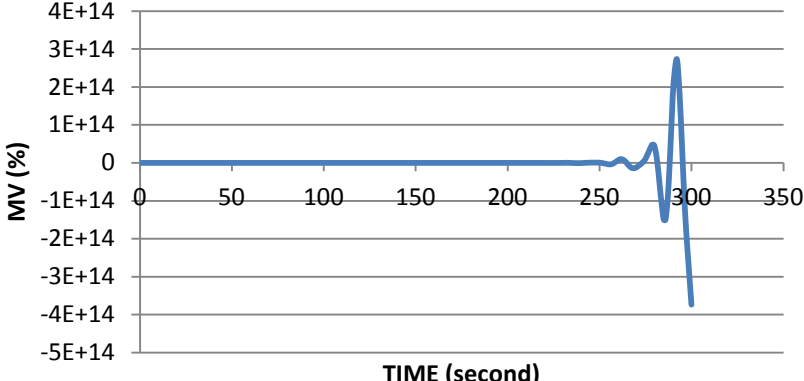
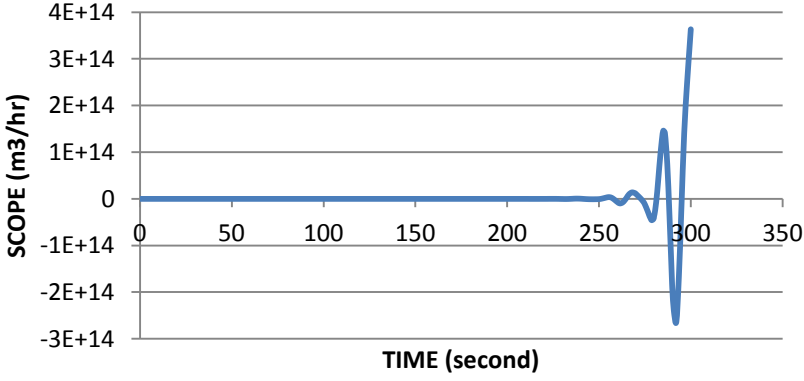
- Cascade control

<div><p><b>MV vs Time</b></p><p>MV (%)</p><p>TIME (second)</p></div>	<p>Area of error =</p> <p>9.59E+91</p> <p>Maintained stable at the beginning at the value of 0 and began increasing drastically at short time.</p>
<div><p><b>Scope vs Time</b></p><p>SCOPE (m3/hr)</p><p>TIME (second)</p></div>	<p>Maintained stable at the beginning at the value of 0 and began decreasing drastically at short time.</p>
<div><p><b>Error vs Time</b></p><p>ERROR (m3/hr)</p><p>TIME (second)</p></div>	<p>Maintained stable at the beginning at the value of 0 and began increasing drastically at short time.</p>

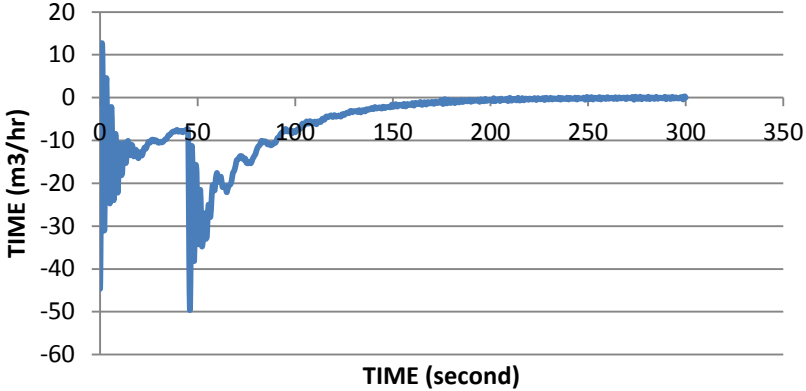
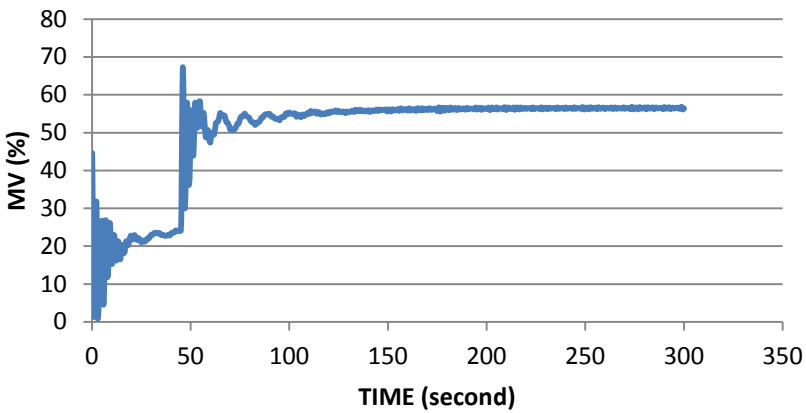
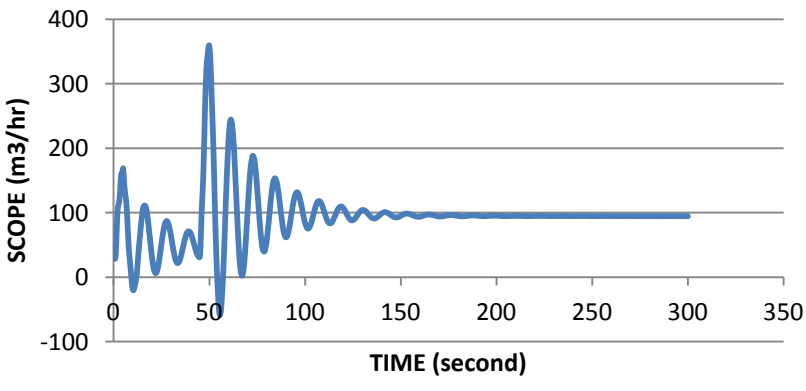
- Feedback Control

<h3>Error vs Time</h3>  <p>The graph displays the error signal over a 350-second period. The y-axis, labeled 'ERROR (m3/hr)', ranges from <math>-6 \times 10^{15}</math> to <math>6 \times 10^{15}</math>. The x-axis, labeled 'TIME (second)', ranges from 0 to 350. The error signal remains at zero for the first 250 seconds. Between 250 and 300 seconds, it exhibits high-frequency oscillations, reaching a peak of approximately <math>4 \times 10^{15}</math> m3/hr and a trough of approximately <math>-4 \times 10^{15}</math> m3/hr.</p>	<p>Area of error: <math>1.36 \times 10^{16}</math></p> <p>Maintained stable at the beginning at the value of 0 and began fluctuating at the end.</p>
<h3>MV vs Time</h3>  <p>The graph displays the manipulated variable (MV) over a 350-second period. The y-axis, labeled 'MV (%)', ranges from <math>-6 \times 10^{15}</math> to <math>6 \times 10^{15}</math>. The x-axis, labeled 'TIME (second)', ranges from 0 to 350. The MV signal remains at zero for the first 250 seconds. Between 250 and 300 seconds, it exhibits high-frequency oscillations, reaching a peak of approximately <math>4 \times 10^{15}</math> % and a trough of approximately <math>-4 \times 10^{15}</math> %.</p>	<p>Maintained stable at the beginning at the value of 0 and began fluctuating at the end.</p>
<h3>Scope vs Time</h3>  <p>The graph displays the process variable (scope) over a 350-second period. The y-axis, labeled 'SCOPE (m3/hr)', ranges from <math>-6 \times 10^{15}</math> to <math>6 \times 10^{15}</math>. The x-axis, labeled 'TIME (second)', ranges from 0 to 350. The scope signal remains at zero for the first 250 seconds. Between 250 and 300 seconds, it exhibits high-frequency oscillations, reaching a peak of approximately <math>4 \times 10^{15}</math> m3/hr and a trough of approximately <math>-4 \times 10^{15}</math> m3/hr.</p>	<p>Maintained stable at the beginning at the value of 0 and began fluctuating at the end.</p>

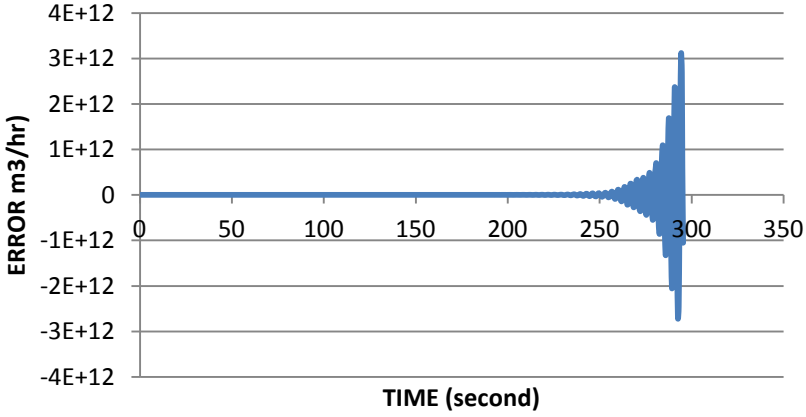
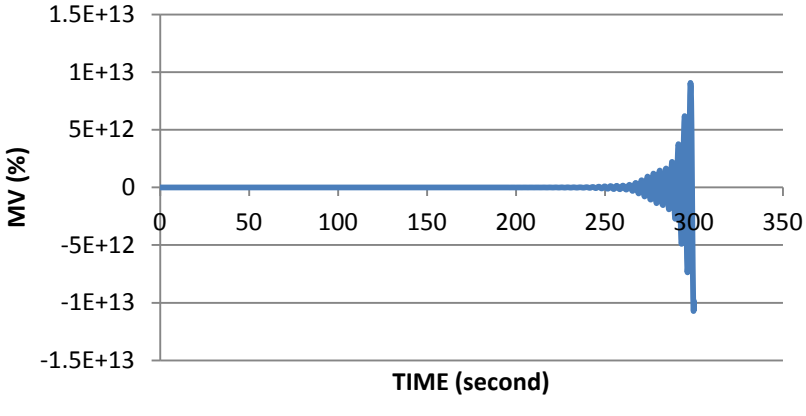
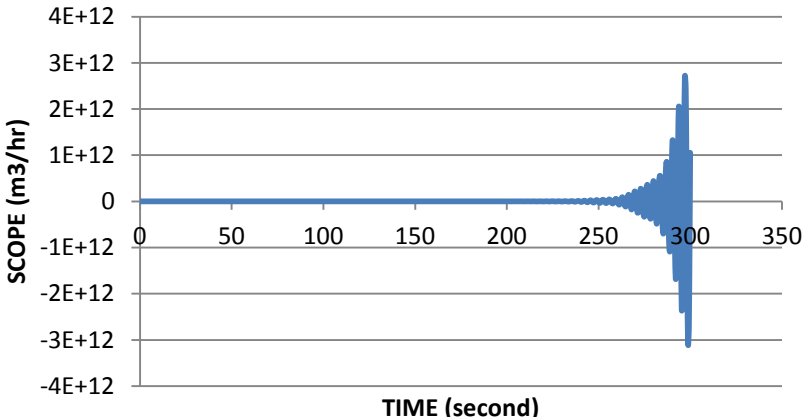
- Feedforward-feedback Control

<h3>Error vs Time</h3>  <p>Y-axis: ERROR (m3/hr) X-axis: TIME (second)</p>	<p>Area of error =</p> <p>3.10E+14</p> <p>Maintained stable at the beginning at the value of 0 and began fluctuating at the end.</p>
<h3>MV vs Time</h3>  <p>Y-axis: MV (%) X-axis: TIME (second)</p>	<p>Maintained stable at the beginning at the value of 0 and began fluctuating at the end.</p>
<h3>Scope vs Time</h3>  <p>Y-axis: SCOPE (m3/hr) X-axis: TIME (second)</p>	<p>Maintained stable at the beginning at the value of 0 and began fluctuating at the end.</p>

- IMC Control

<h3>Error vs Time</h3>  <p>TIME (m3/hr)</p> <p>TIME (second)</p>	<p>Area of error =</p> <p>1.71E+03</p> <p>Fluctuating at the beginning and then maintained stable until the end of process.</p>
<h3>MV vs Time</h3>  <p>MV (%)</p> <p>TIME (second)</p>	<p>Fluctuating at the beginning and then maintained stable until the end of process.</p>
<h3>Scope vs Time</h3>  <p>SCOPE (m3/hr)</p> <p>TIME (second)</p>	<p>Fluctuating at the beginning and then maintained stable until the end of process.</p>

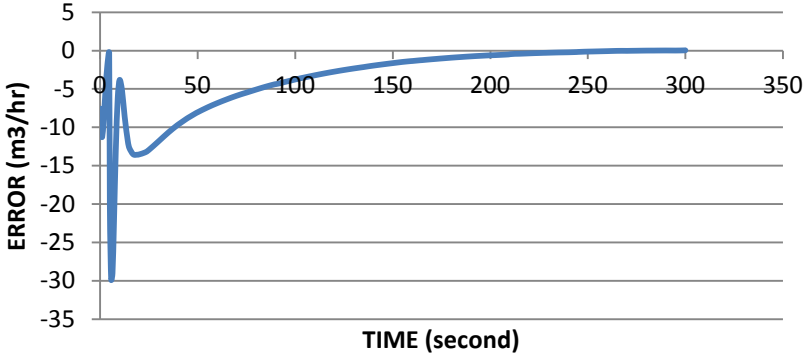
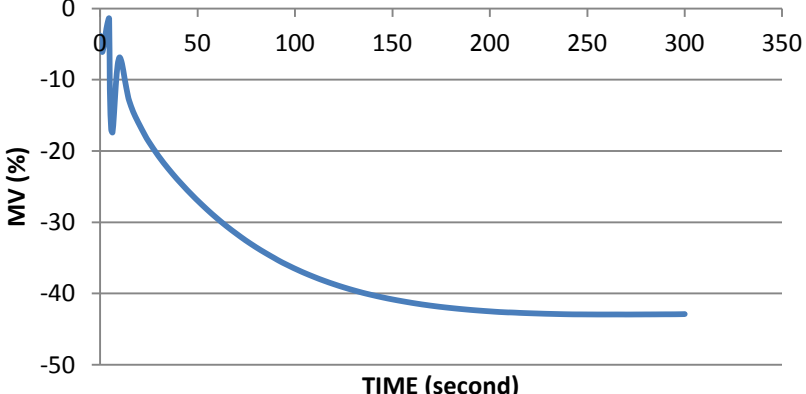
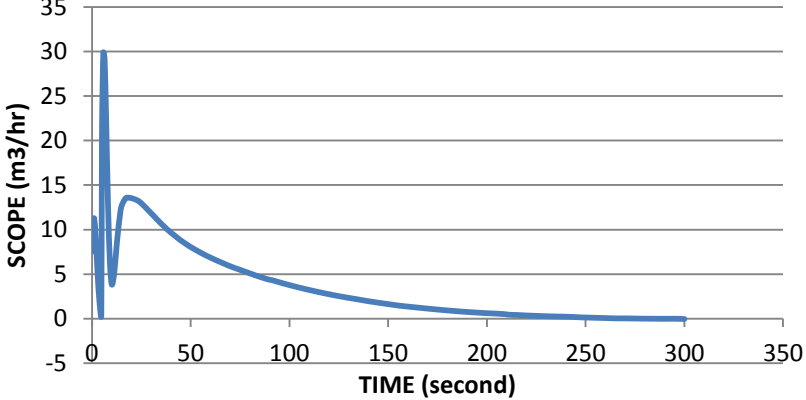
- Smith Control

<h3>Error vs Time</h3>  <p>Y-axis: ERROR m3/hr (ranging from -4E+12 to 4E+12) X-axis: TIME (second) (ranging from 0 to 350)</p>	<p>Area of error =</p> <p>1.74E+12</p> <p>Maintained stable at the beginning at the value of 0 and began fluctuating at the end.</p>
<h3>MV vs Time</h3>  <p>Y-axis: MV (%) (ranging from -1.5E+13 to 1.5E+13) X-axis: TIME (second) (ranging from 0 to 350)</p>	<p>Maintained stable at the beginning at the value of 0 and began fluctuating at the end.</p>
<h3>Scope vs Time</h3>  <p>Y-axis: SCOPE (m3/hr) (ranging from -4E+12 to 4E+12) X-axis: TIME (second) (ranging from 0 to 350)</p>	<p>Maintained stable at the beginning at the value of 0 and began fluctuating at the end.</p>

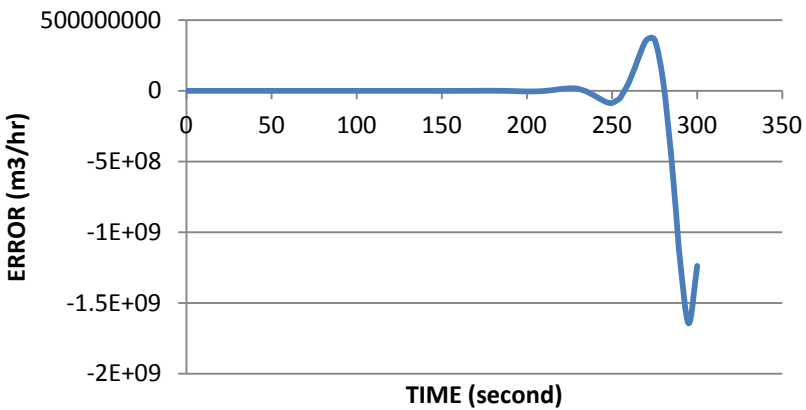
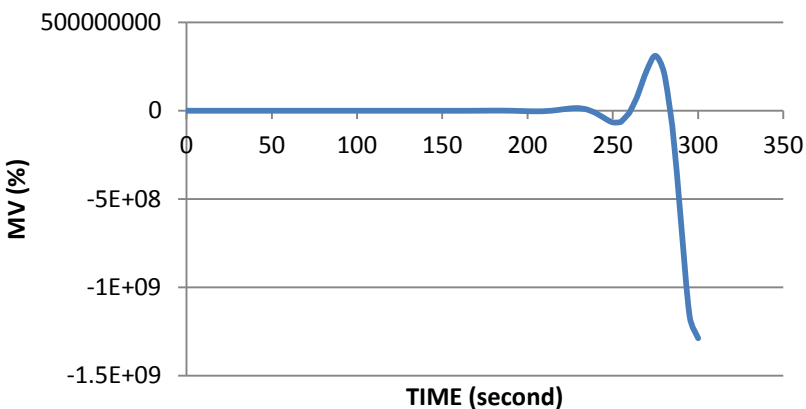
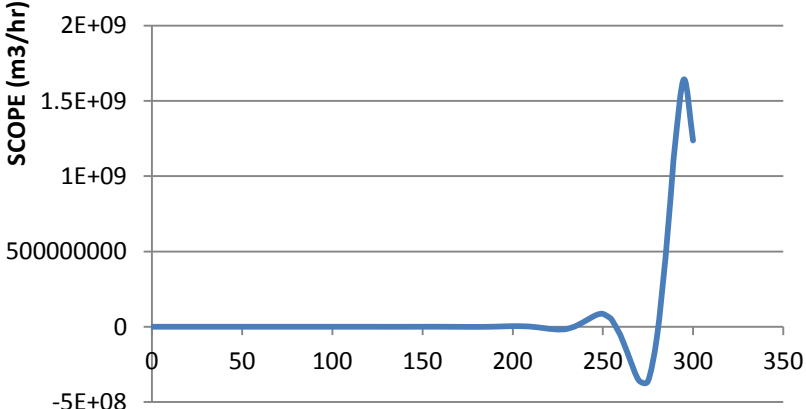


### 7.1.2 FLOW2

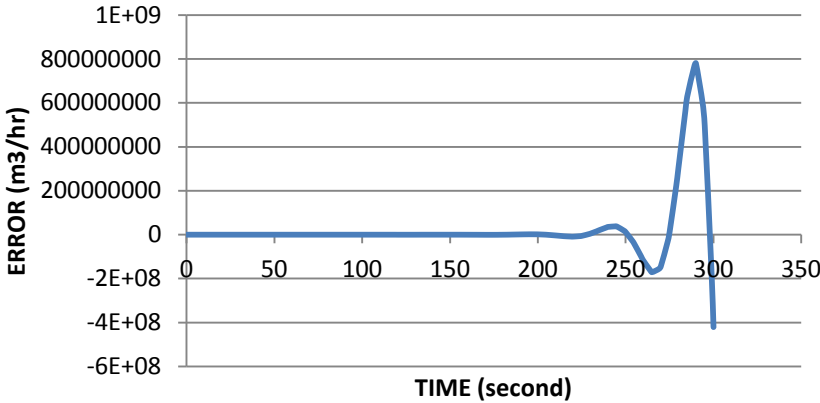
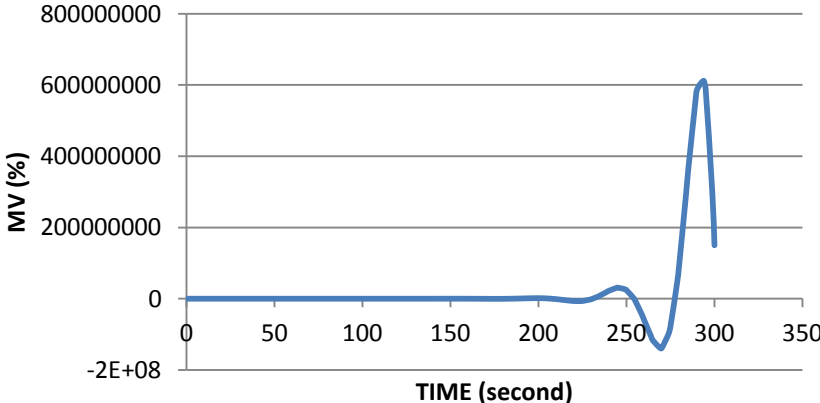
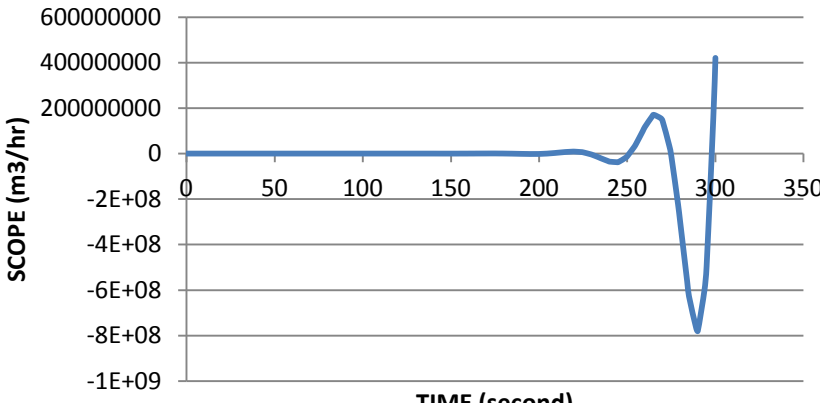
- Cascade Control

<p style="text-align: center;"><b>Error vs Time</b></p>  <p>The graph shows the error signal in m³/hr over a 350-second period. The y-axis ranges from -35 to 5. The error starts at 0, drops sharply to a minimum of approximately -30 m³/hr at 10 seconds, then rises to a local maximum of about -5 m³/hr at 20 seconds, before settling into a smooth, gradual decay towards 0 m³/hr, reaching near-stability by 300 seconds.</p>	<p>Area of error =</p> <p style="text-align: center;">1.03E+03</p> <p>Fluctuating at the beginning and maintained stable until the end process.</p>
<p style="text-align: center;"><b>MV vs Time</b></p>  <p>The graph displays the manipulated variable (MV) in percent over 350 seconds. The y-axis ranges from -50 to 0. The signal starts at 0, exhibits a small initial fluctuation, and then begins a steady, nearly linear decrease, reaching a stable value of approximately -45% by the 300-second mark.</p>	<p>Fluctuating at the beginning and the value keep decreasing until negative value.</p>
<p style="text-align: center;"><b>Scope vs Time</b></p>  <p>The graph illustrates the process output (SCOPE) in m³/hr over 350 seconds. The y-axis ranges from -5 to 35. The signal starts at 0, spikes to a peak of about 30 m³/hr at 10 seconds, drops to a local minimum of 5 m³/hr at 20 seconds, rises to a second peak of 15 m³/hr at 30 seconds, and then gradually decays, returning to 0 m³/hr by 300 seconds.</p>	<p>Fluctuating at the beginning and maintained stable until the end process.</p>

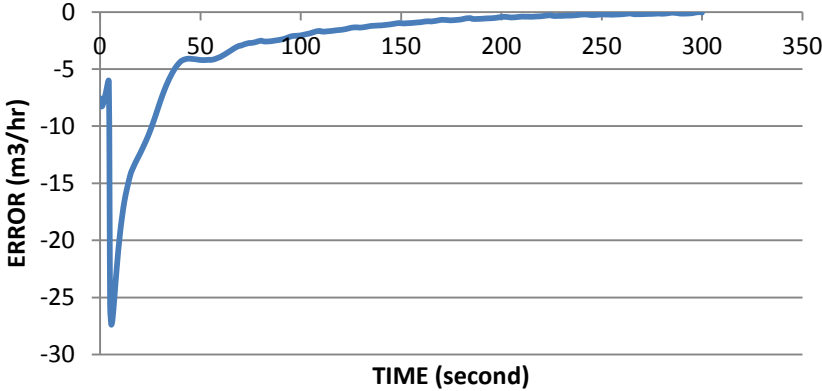
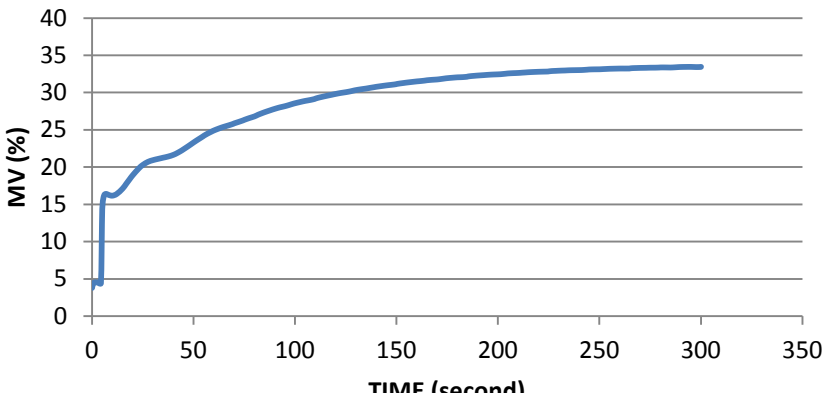
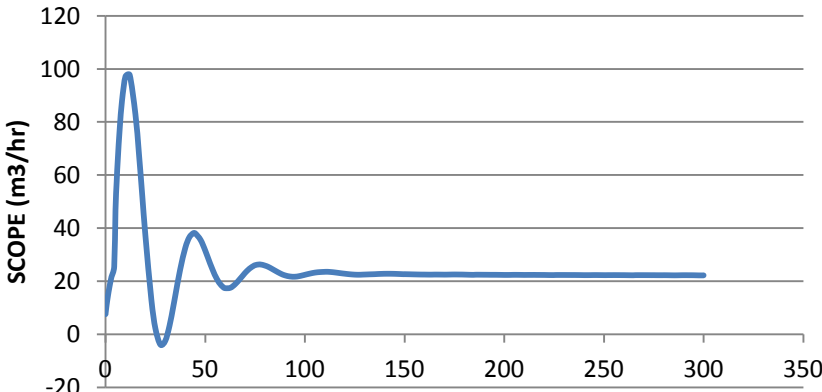
- Feedback Control

<h3>Error vs Time</h3>  <p>Y-axis: ERROR (m3/hr) X-axis: TIME (second)</p>	<p>Area of error =</p> <p>1.55E+10</p> <p>Maintained stable at 0 value at the beginning of process and begin to fluctuate to negative value at the end.</p>
<h3>MV vs Time</h3>  <p>Y-axis: MV (%) X-axis: TIME (second)</p>	<p>Maintained stable at 0 value at the beginning of process and begin to fluctuate to negative value at the end.</p>
<h3>Scope vs Time</h3>  <p>Y-axis: SCOPE (m3/hr) X-axis: TIME (second)</p>	<p>Maintained stable at 0 value at the beginning of process and begin to fluctuate to positive value at the end.</p>

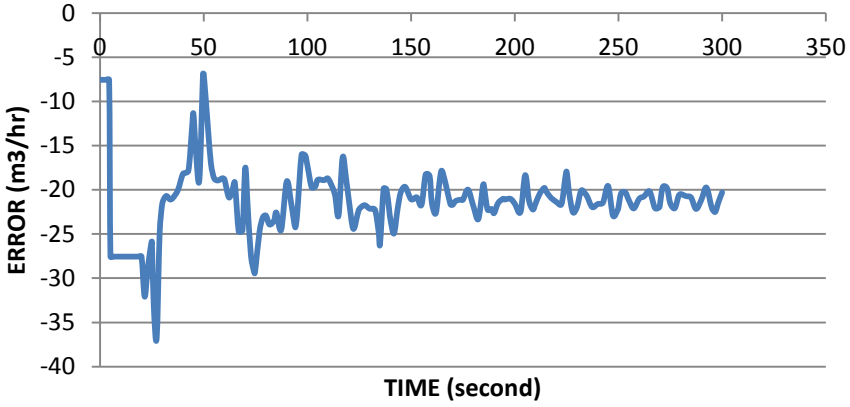
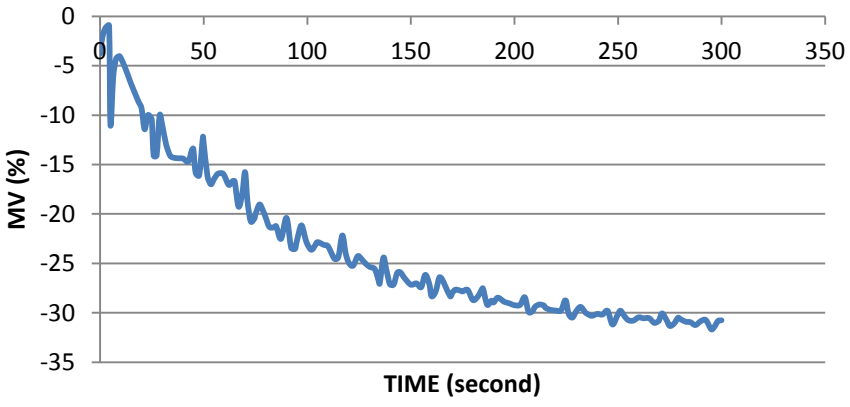
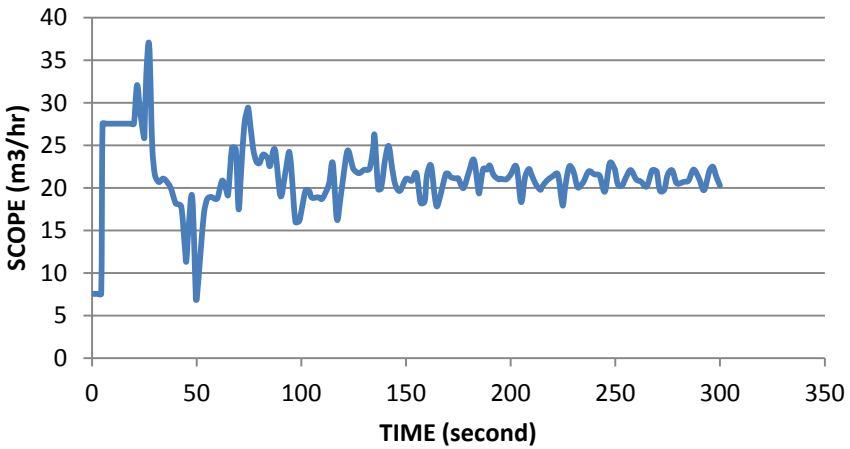
- Feedforward-feedback Control

<h3>Error vs Time</h3>  <p>The plot shows the error signal over a 350-second period. The y-axis ranges from -6E+08 to 1E+09 m3/hr. The error remains at zero until approximately 250 seconds, where it begins to fluctuate. It reaches a sharp positive peak of about 8.29E+09 m3/hr at 300 seconds before dropping sharply.</p>	<p>Area of error =</p> <p>8.29E+09</p> <p>Maintained stable at 0 value at the beginning of process and begin to fluctuate to positive value at the end.</p>
<h3>MV vs Time</h3>  <p>The plot shows the manipulated variable (MV) over a 350-second period. The y-axis ranges from -2E+08 to 8E+08 %. The MV remains at zero until approximately 250 seconds, where it begins to fluctuate. It reaches a sharp positive peak of about 6E+08 % at 300 seconds before dropping sharply.</p>	<p>Maintained stable at 0 value at the beginning of process and begin to fluctuate to positive value at the end.</p>
<h3>Scope vs Time</h3>  <p>The plot shows the process output (scope) over a 350-second period. The y-axis ranges from -1E+09 to 6E+08 m3/hr. The scope remains at zero until approximately 250 seconds, where it begins to fluctuate. It reaches a sharp positive peak of about 4E+08 m3/hr at 300 seconds before dropping sharply.</p>	<p>Maintained stable at 0 value at the beginning of process and begin to fluctuate to negative value at the end.</p>

- IMC Control

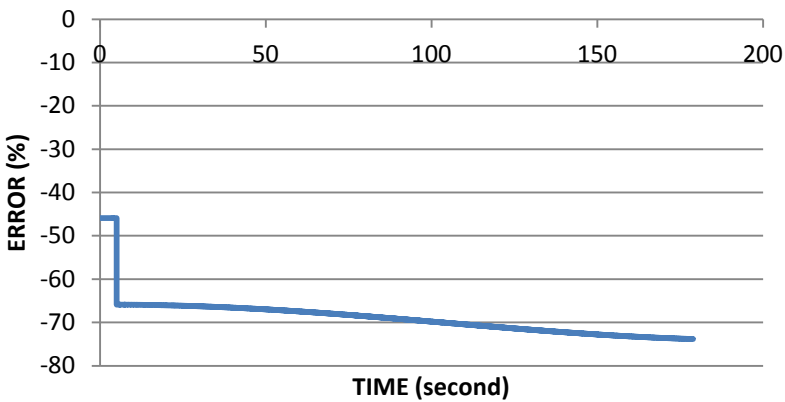
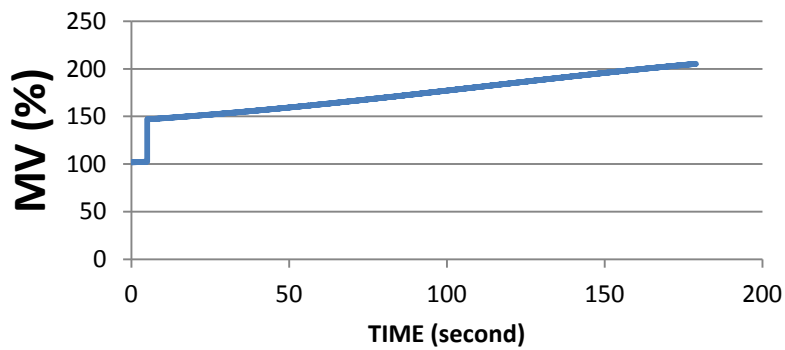
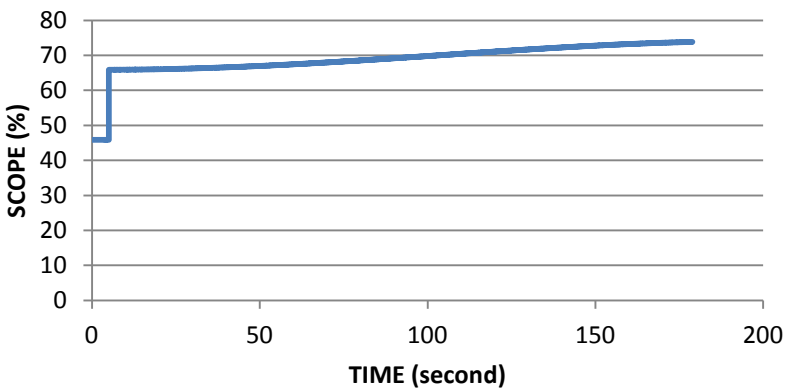
<p style="text-align: center;"><b>Error vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Area of error =</p> <p style="text-align: center;">97.865</p> <p>Fluctuating at the beginning and maintained stable until the end process</p>
<p style="text-align: center;"><b>MV vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Fluctuating at the beginning and maintained stable until the end process</p>
<p style="text-align: center;"><b>Scope vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Fluctuating at the beginning and maintained stable until the end process</p>

- Smith Control

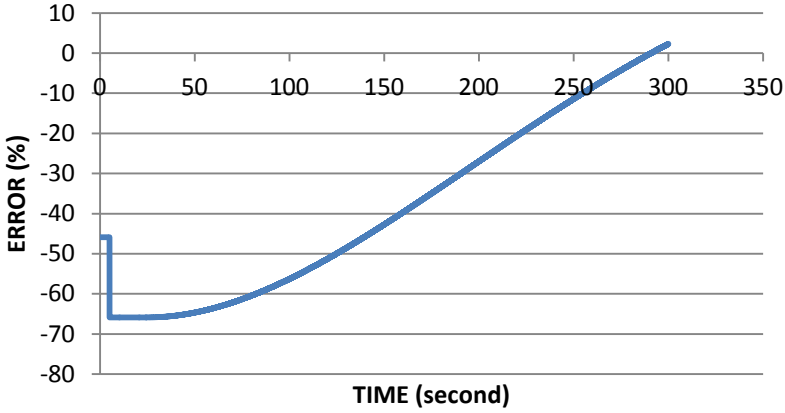
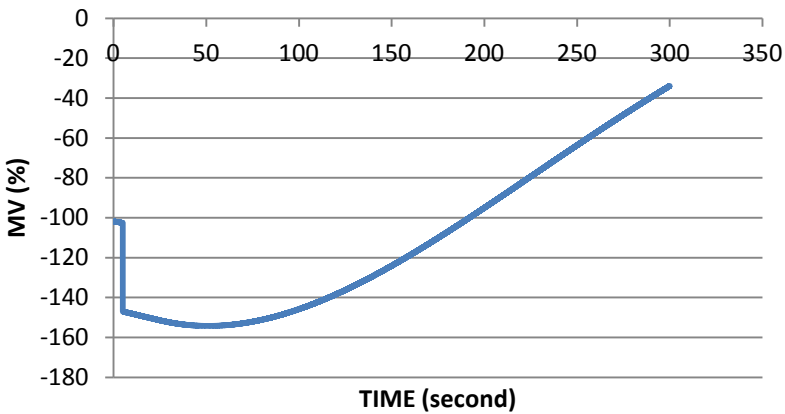
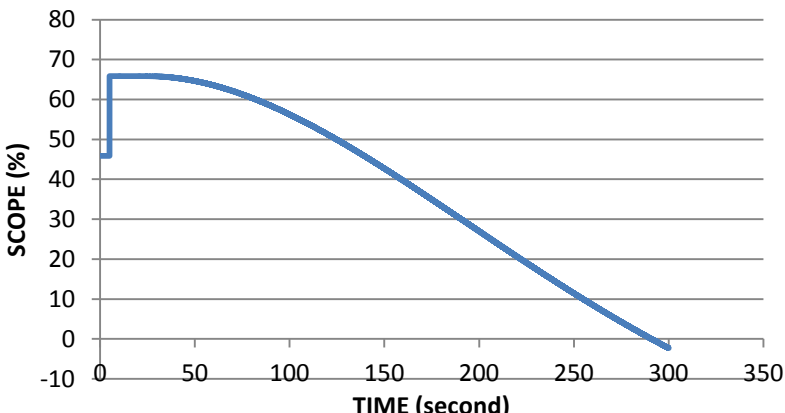
<p style="text-align: center;"><b>Error vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Area of error = 6.37E+03</p> <p>Fluctuating and unstable</p>
<p style="text-align: center;"><b>MV vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Fluctuating and unstable</p>
<p style="text-align: center;"><b>Scope Vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Fluctuating and unstable</p>

7.1.3 LEVEL1

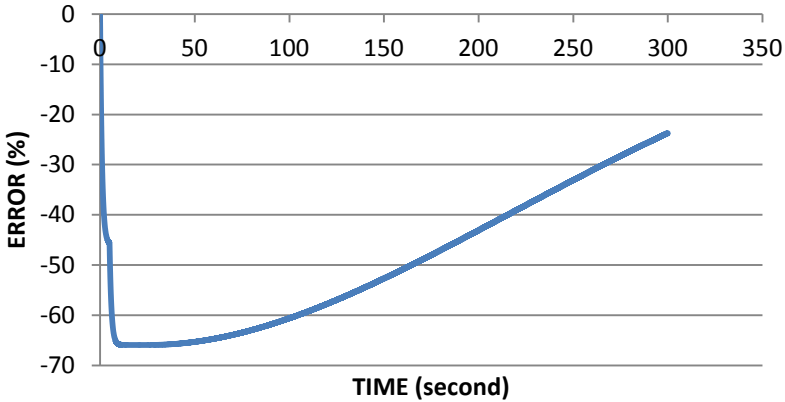
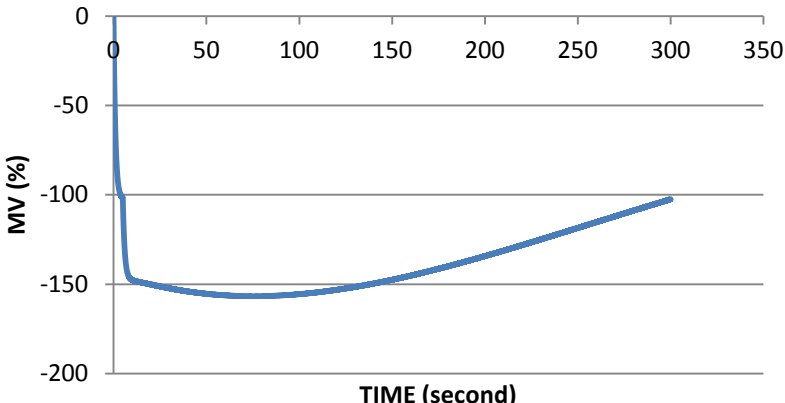
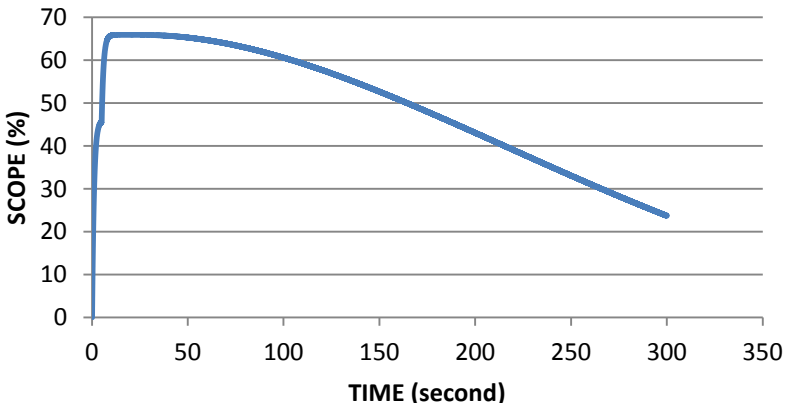
- Cascade Control

<p><b>Error vs Time</b></p>  <p>Area of error = 2.10E+04 Unstable</p>	
<p><b>MV vs Time</b></p>  <p>Stable</p>	
<p><b>Scope vs Time</b></p>  <p>Stable</p>	

- Feedback Control

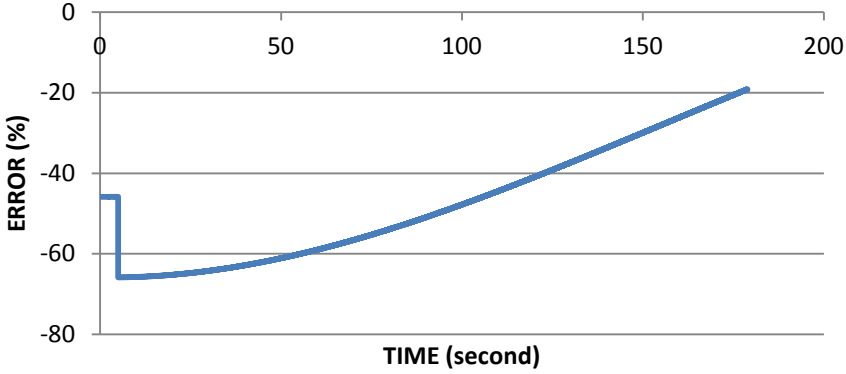
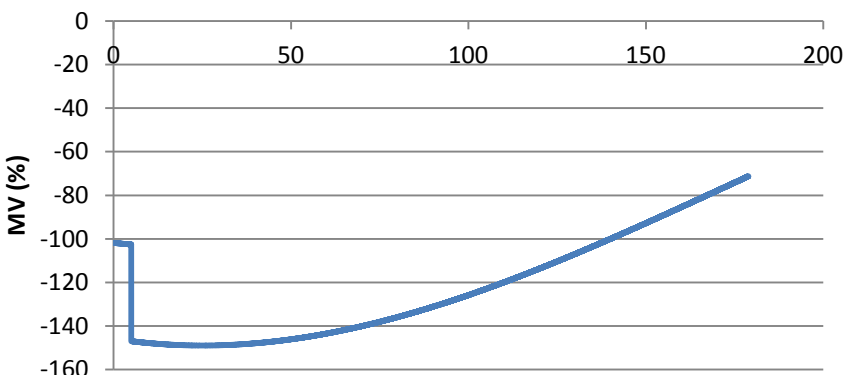
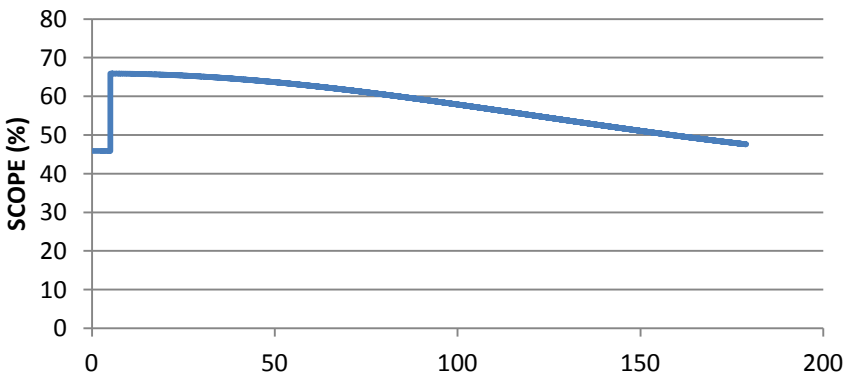
<h3>Error vs Time</h3>  <p>The graph shows the error percentage over time. The y-axis is labeled 'ERROR (%)' and ranges from -80 to 10. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The error starts at -50% at 0 seconds, drops sharply to -65% by 10 seconds, remains constant until 20 seconds, then gradually rises to 0% at 300 seconds.</p>	<p>Area of error =</p> <p>1.16E+04</p> <p>Unstable and has negative value.</p>
<h3>MV vs Time</h3>  <p>The graph shows the MV percentage over time. The y-axis is labeled 'MV (%)' and ranges from -180 to 0. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The MV starts at -100% at 0 seconds, drops sharply to -150% by 10 seconds, remains constant until 20 seconds, then gradually rises to -30% at 300 seconds.</p>	<p>Unstable and has negative value.</p>
<h3>Scope vs Time</h3>  <p>The graph shows the scope percentage over time. The y-axis is labeled 'SCOPE (%)' and ranges from -10 to 80. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The scope starts at 65% at 0 seconds, remains constant until 50 seconds, then gradually decreases to 0% at 300 seconds.</p>	<p>Stable at the beginning and then begin decreased constantly.</p>

- Feedforward-feedback

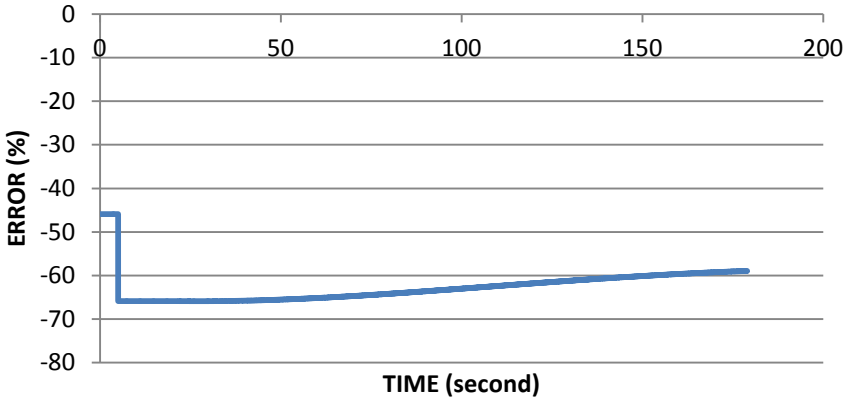
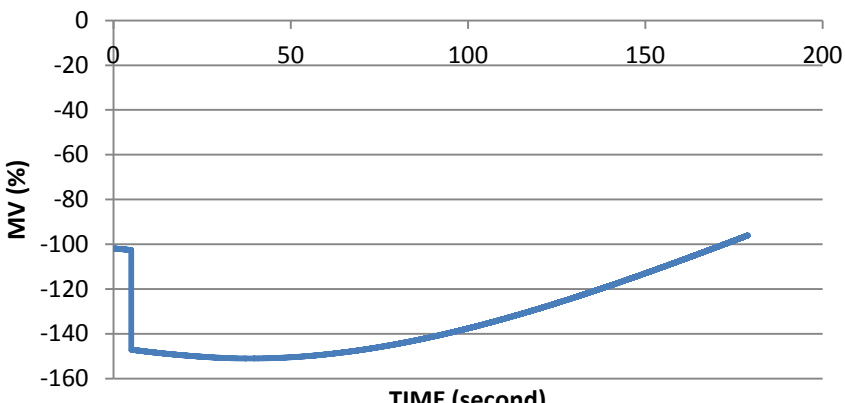
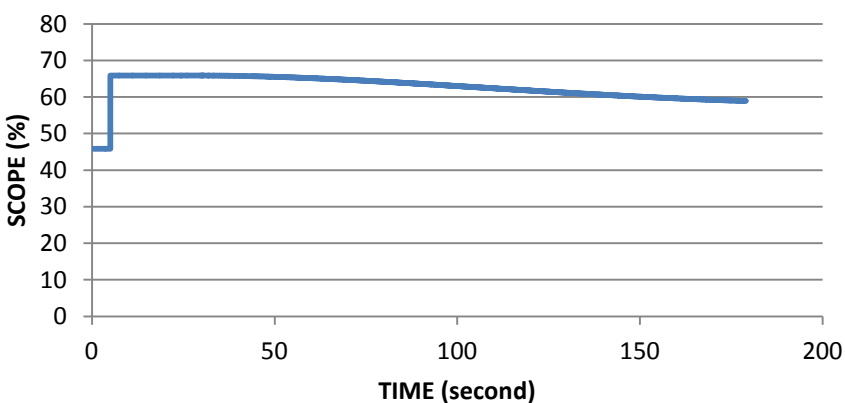
<h3>Error vs Time</h3>  <p>The graph shows the error percentage over time. The y-axis is labeled 'ERROR (%)' and ranges from 0 to -70. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The error starts at 0, drops sharply to approximately -65% at 10 seconds, and then gradually increases to approximately -25% at 300 seconds.</p>	<p>Area of error =</p> <p>1.48E+04</p> <p>Unstable and has negative value.</p>
<h3>MV vs Time</h3>  <p>The graph shows the MV percentage over time. The y-axis is labeled 'MV (%)' and ranges from 0 to -200. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The MV starts at 0, drops sharply to approximately -150% at 10 seconds, and then gradually increases to approximately -100% at 300 seconds.</p>	<p>Unstable and has negative value.</p>
<h3>Scope vs Time</h3>  <p>The graph shows the scope percentage over time. The y-axis is labeled 'SCOPE (%)' and ranges from 0 to 70. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The scope starts at 0, rises sharply to approximately 65% at 10 seconds, and then gradually decreases to approximately 25% at 300 seconds.</p>	<p>Stable at the beginning and then begin decreased constantly.</p>



- IMC Control

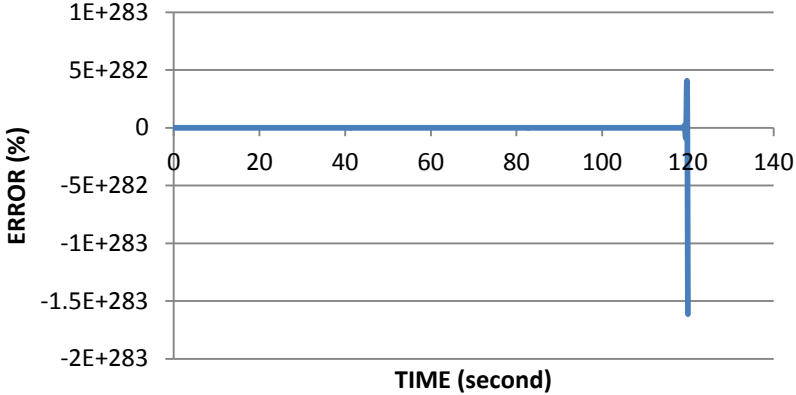
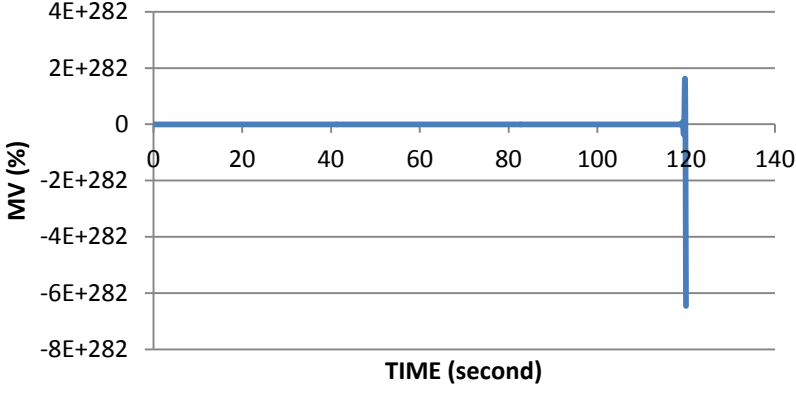
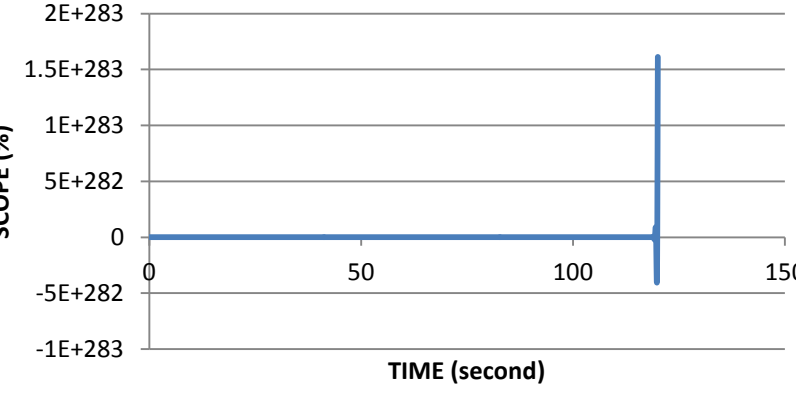
<p style="text-align: center;"><b>Error vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Area of error =</p> <p style="text-align: center;"><math>8.53E+03</math></p> <p>Unstable and has negative value.</p>
<p style="text-align: center;"><b>MV vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Unstable and has negative value.</p>
<p style="text-align: center;"><b>Scope vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Stable</p>

- Smith Control

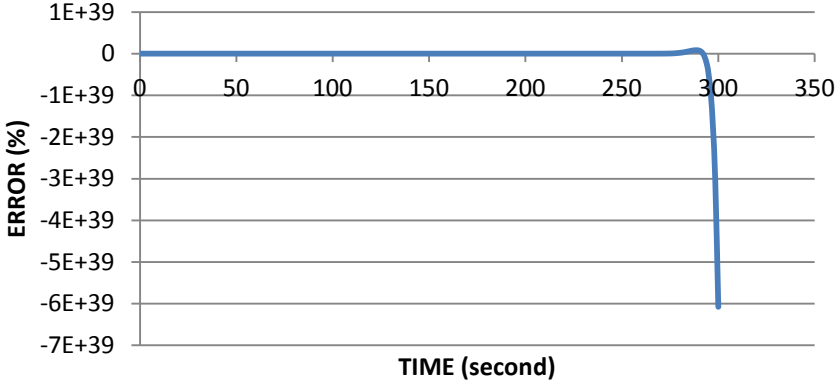
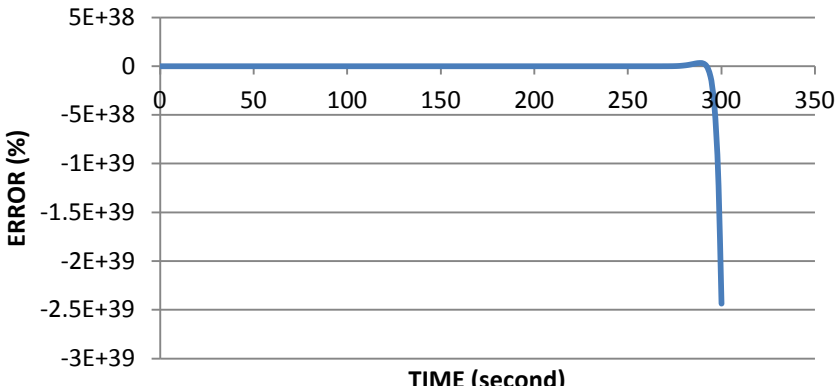
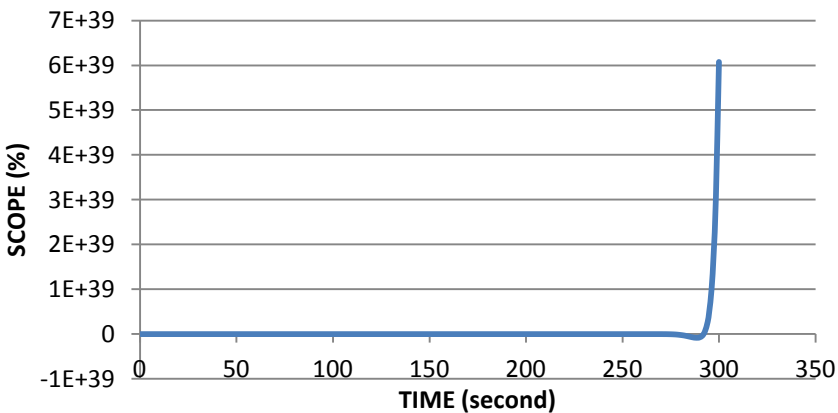
<p style="text-align: center;"><b>Error vs Time</b></p>  <p>The graph shows the error percentage over time. The y-axis is labeled 'ERROR (%)' and ranges from 0 to -80. The x-axis is labeled 'TIME (second)' and ranges from 0 to 200. The error starts at -45% at 0 seconds, drops sharply to -65% at 5 seconds, and then slowly rises to -60% at 180 seconds.</p>	<p>Area of error = 1.84E+04</p> <p>Unstable and has negative value</p>
<p style="text-align: center;"><b>MV vs Time</b></p>  <p>The graph shows the MV percentage over time. The y-axis is labeled 'MV (%)' and ranges from 0 to -160. The x-axis is labeled 'TIME (second)' and ranges from 0 to 200. The MV starts at -100% at 0 seconds, drops sharply to -150% at 5 seconds, and then slowly rises to -100% at 180 seconds.</p>	<p>Unstable and has negative value</p>
<p style="text-align: center;"><b>Scope vs Time</b></p>  <p>The graph shows the scope percentage over time. The y-axis is labeled 'SCOPE (%)' and ranges from 0 to 80. The x-axis is labeled 'TIME (second)' and ranges from 0 to 200. The scope starts at 45% at 0 seconds, jumps to 65% at 5 seconds, and then slowly decreases to 60% at 180 seconds.</p>	<p>Stable</p>

7.1.4 LEVEL2

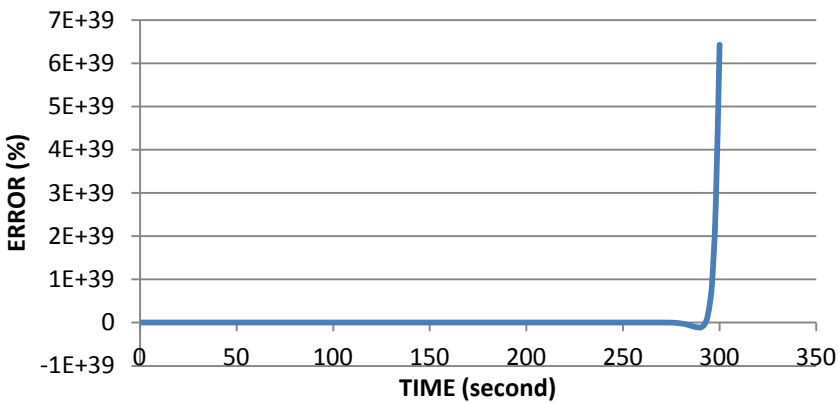
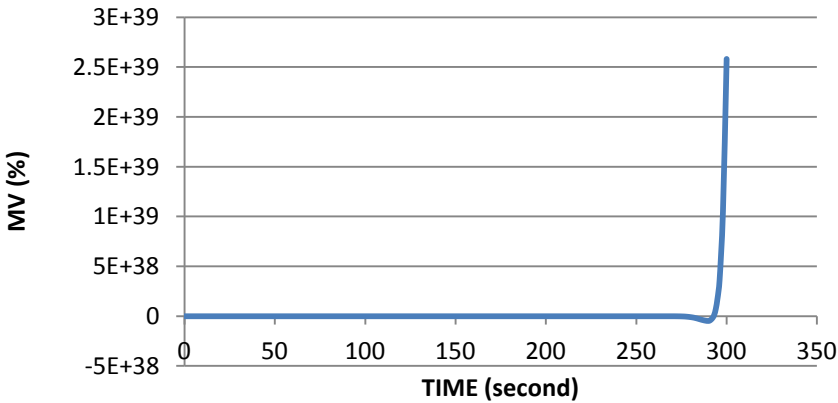
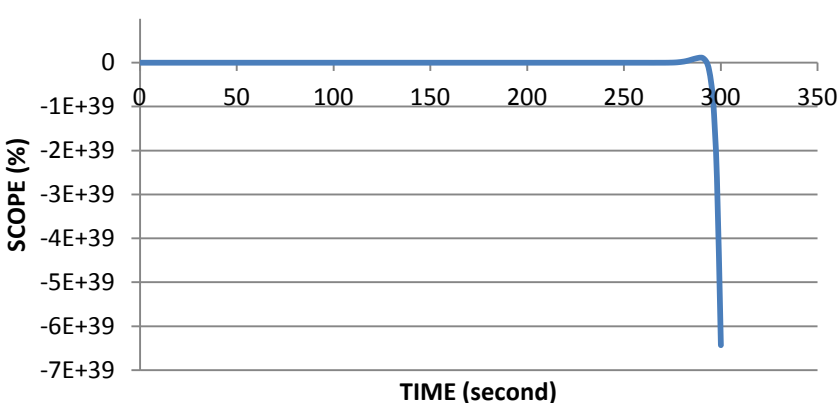
- Cascade

<p><b>Error vs Time</b></p>  <p>1E+283 5E+282 0 -5E+282 -1E+283 -1.5E+283 -2E+283</p> <p>ERROR (%)</p> <p>0 20 40 60 80 100 120 140</p> <p>TIME (second)</p>	<p>Area of error = 1.93E+285</p> <p>Stable at the beginning and begin to fluctuate to negative value at the end.</p>
<p><b>MV vs Time</b></p>  <p>4E+282 2E+282 0 -2E+282 -4E+282 -6E+282 -8E+282</p> <p>MV (%)</p> <p>0 20 40 60 80 100 120 140</p> <p>TIME (second)</p>	<p>Stable at the beginning and begin to fluctuate to negative value at the end.</p>
<p><b>Scope vs Time</b></p>  <p>2E+283 1.5E+283 1E+283 5E+282 0 -5E+282 -1E+283</p> <p>SCOPE (%)</p> <p>0 50 100 150</p> <p>TIME (second)</p>	<p>Stable at the beginning and begin to fluctuate to negative value at the end.</p>

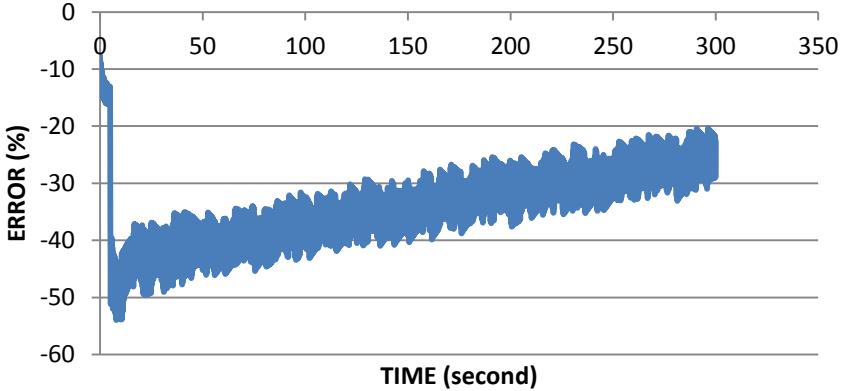
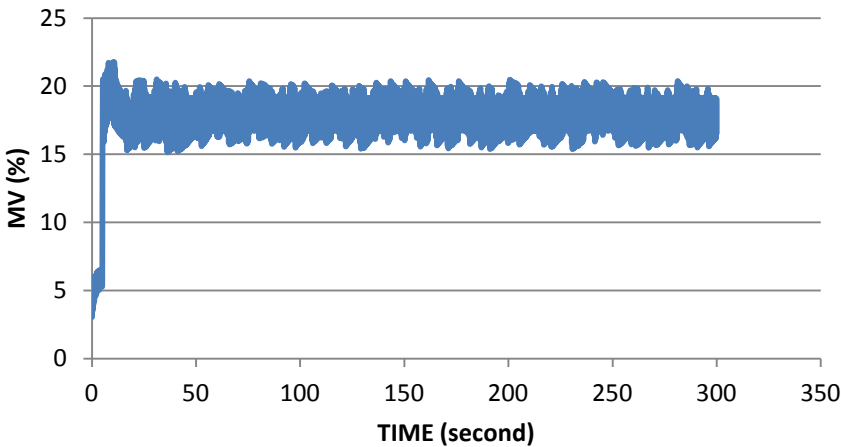
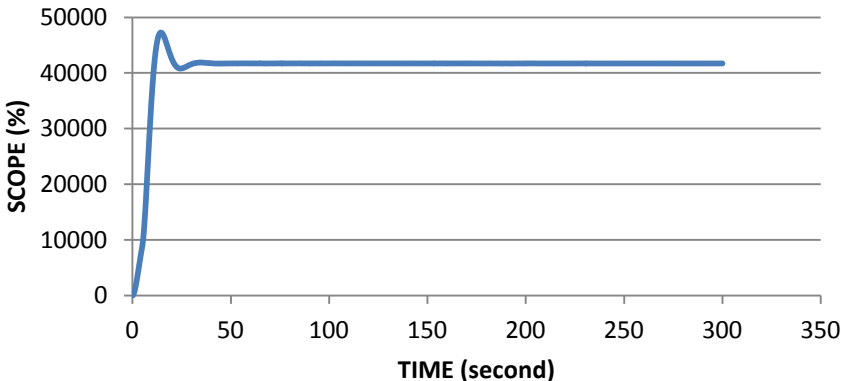
- Feedback Control

<h3>Error vs Time</h3>  <p>The graph shows the error percentage over time. The y-axis ranges from -7E+39 to 1E+39, and the x-axis ranges from 0 to 350 seconds. The error is stable at 0 until approximately 280 seconds, then drops sharply to -6E+39.</p>	<p>Area of error =</p> <p>1.23E+40</p> <p>Stable at the beginning and begin to fluctuate to negative value at the end</p>
<h3>MV vs Time</h3>  <p>The graph shows the error percentage over time. The y-axis ranges from -3E+39 to 5E+38, and the x-axis ranges from 0 to 350 seconds. The error is stable at 0 until approximately 280 seconds, then drops sharply to -2.5E+39.</p>	<p>Stable at the beginning and begin to fluctuate to negative value at the end</p>
<h3>Scope vs Time</h3>  <p>The graph shows the scope percentage over time. The y-axis ranges from -1E+39 to 7E+39, and the x-axis ranges from 0 to 350 seconds. The scope is stable at 0 until approximately 280 seconds, then rises sharply to 6E+39.</p>	<p>Stable at the beginning and begin to fluctuate to positive value in short time</p>

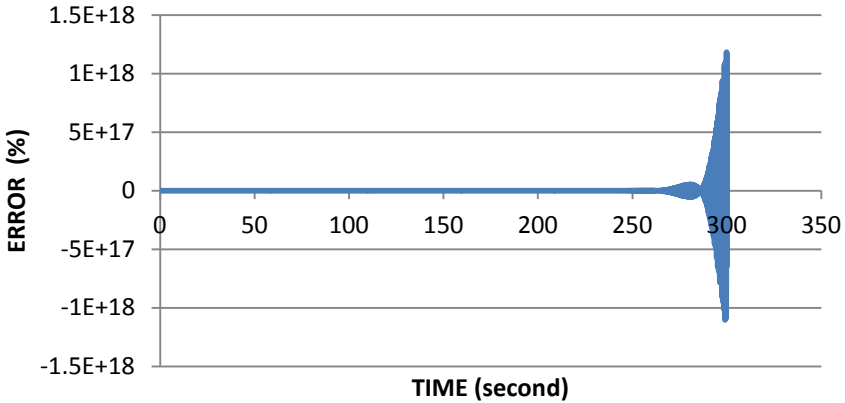
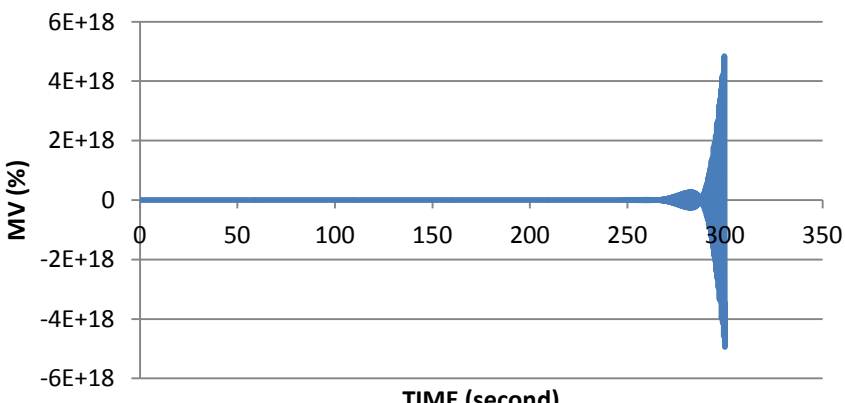
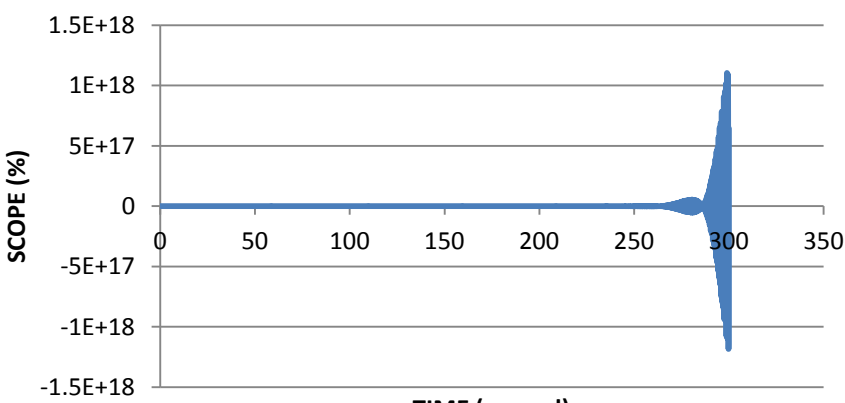
- Feedforward-feedback Control

<h3>Error vs Time</h3>  <p>The graph shows the error percentage over time. The y-axis ranges from -1E+39 to 7E+39. The x-axis ranges from 0 to 350 seconds. The error is zero until approximately 280 seconds, where it begins to rise sharply, reaching a peak of about 6.5E+39 at 300 seconds.</p>	<p>Area of error =</p> <p>1.27E+40</p> <p>Stable at the beginning and begin to fluctuate to positive value in short time</p>
<h3>MV vs Time</h3>  <p>The graph shows the MV percentage over time. The y-axis ranges from -5E+38 to 3E+39. The x-axis ranges from 0 to 350 seconds. The MV is zero until approximately 280 seconds, where it begins to rise sharply, reaching a peak of about 2.5E+39 at 300 seconds.</p>	<p>Stable at the beginning and begin to fluctuate to positive value in short time</p>
<h3>Scope vs Time</h3>  <p>The graph shows the scope percentage over time. The y-axis ranges from -7E+39 to 0. The x-axis ranges from 0 to 350 seconds. The scope is zero until approximately 280 seconds, where it begins to drop sharply, reaching a minimum of about -6.5E+39 at 300 seconds.</p>	<p>Stable at the beginning and begin to fluctuate to negative value in short time</p>

- IMC Control

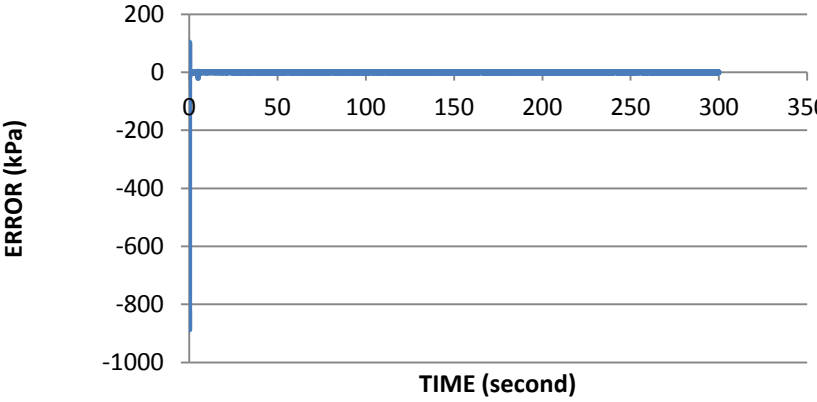
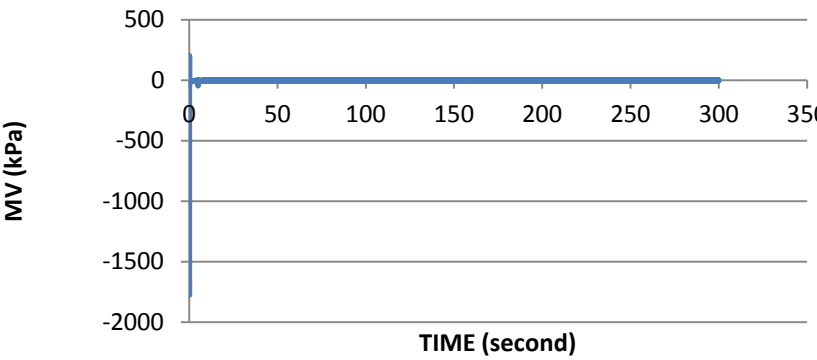
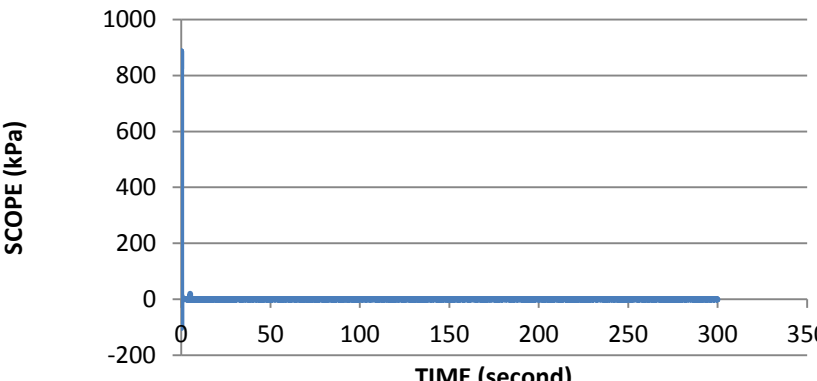
<p style="text-align: center;"><b>Error vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Area of error =</p> <p style="text-align: center;">-1.03E+04</p> <p>Fluctuated and has negative value</p>
<p style="text-align: center;"><b>MV vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Fluctuated and stable</p>
<p style="text-align: center;"><b>Scope vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Fluctuated at the beginning and begin stable until the end of process</p>

- Smith Control

<p style="text-align: center;"><b>Error vs Time</b></p>  <p>The plot shows the error percentage over time. The y-axis ranges from -1.5E+18 to 1.5E+18, and the x-axis ranges from 0 to 350 seconds. The error is zero until approximately 280 seconds, where it begins to fluctuate, reaching a sharp peak of about 1.2E+18 at 300 seconds before returning to zero.</p>	<p>Area of error = 8.02E+16</p> <p>Fluctuated and unstable</p>
<p style="text-align: center;"><b>MV vs Time</b></p>  <p>The plot shows the manipulated variable (MV) percentage over time. The y-axis ranges from -6E+18 to 6E+18, and the x-axis ranges from 0 to 350 seconds. The MV is zero until approximately 280 seconds, where it begins to fluctuate, reaching a sharp peak of about 5E+18 at 300 seconds before returning to zero.</p>	<p>Fluctuated and unstable</p>
<p style="text-align: center;"><b>Scope vs Time</b></p>  <p>The plot shows the scope percentage over time. The y-axis ranges from -1.5E+18 to 1.5E+18, and the x-axis ranges from 0 to 350 seconds. The scope is zero until approximately 280 seconds, where it begins to fluctuate, reaching a sharp peak of about 1.2E+18 at 300 seconds before returning to zero.</p>	<p>Fluctuated and unstable</p>

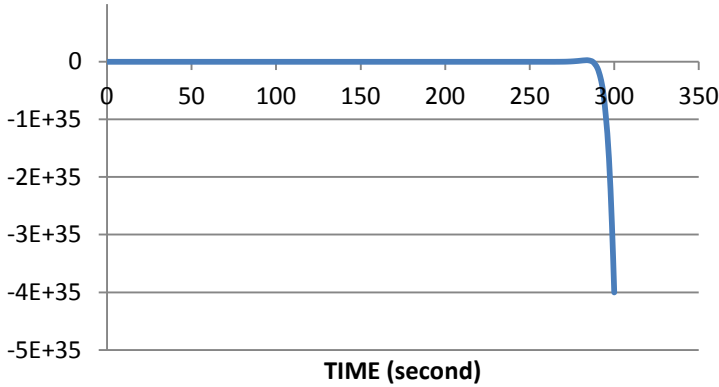
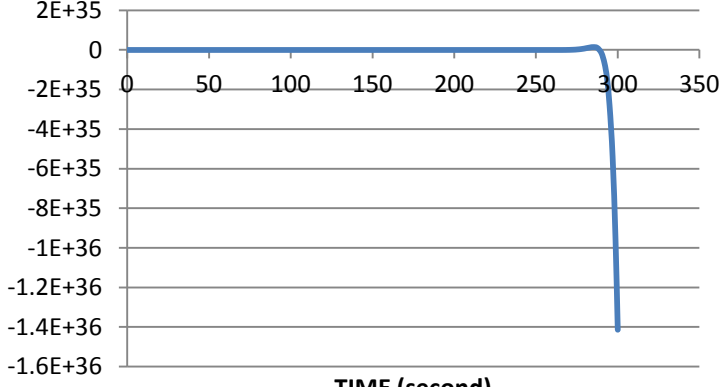
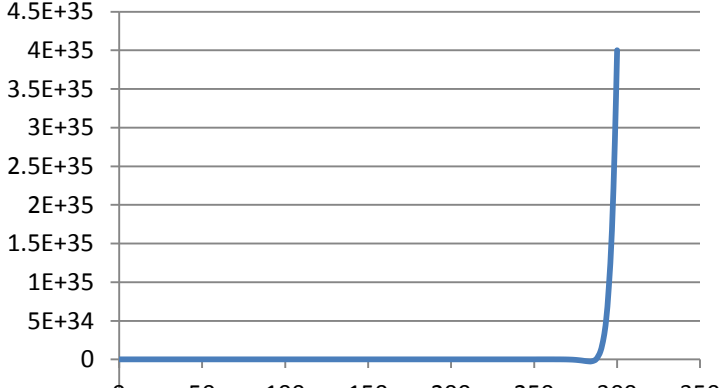
### 7.1.5 PRESSURE1

- Cascade

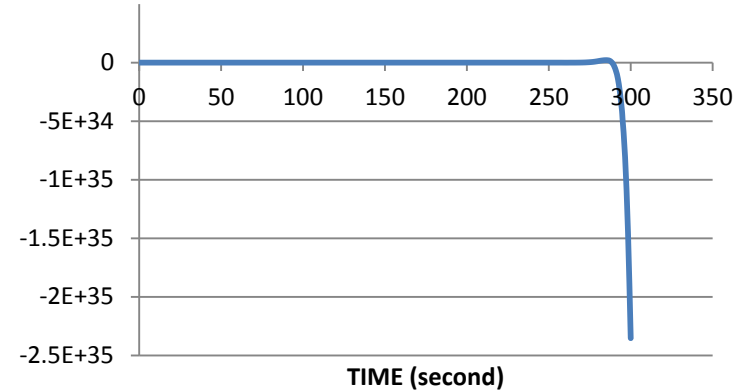
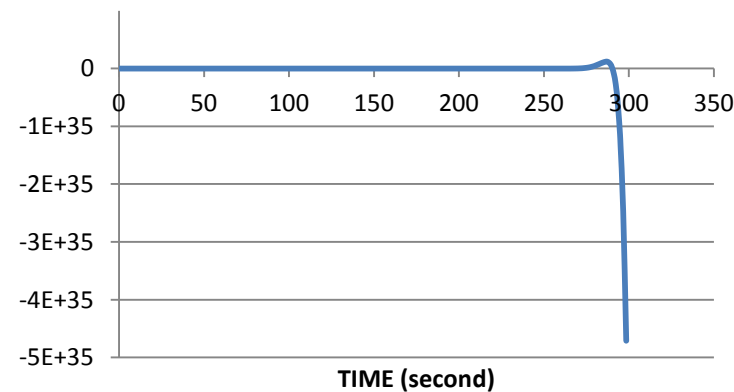
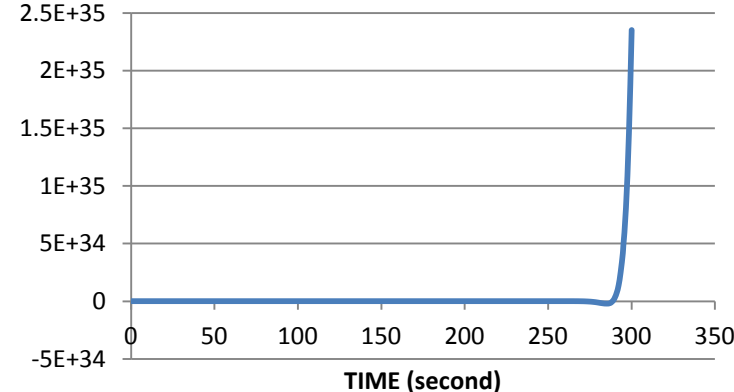
<p><b>Error vs Time</b></p>  <p>The plot shows the error signal over a 350-second period. The y-axis, labeled 'ERROR (kPa)', ranges from -1000 to 200. The x-axis, labeled 'TIME (second)', ranges from 0 to 350. The error signal is a blue line that remains at zero for the entire duration, with a small initial spike at t=0.</p>	<p>Area of error =</p> <p>1.354</p> <p>Unstable as the value stayed only at zero</p>
<p><b>MV vs Time</b></p>  <p>The plot shows the manipulated variable (MV) over a 350-second period. The y-axis, labeled 'MV (kPa)', ranges from -2000 to 500. The x-axis, labeled 'TIME (second)', ranges from 0 to 350. The MV signal is a blue line that remains at zero for the entire duration, with a small initial spike at t=0.</p>	<p>Unstable as the value stayed only at zero</p>
<p><b>Scope vs Time</b></p>  <p>The plot shows the process variable (SCOPE) over a 350-second period. The y-axis, labeled 'SCOPE (kPa)', ranges from -200 to 1000. The x-axis, labeled 'TIME (second)', ranges from 0 to 350. The SCOPE signal is a blue line that remains at zero for the entire duration, with a small initial spike at t=0.</p>	<p>Unstable as the value stayed only at zero</p>



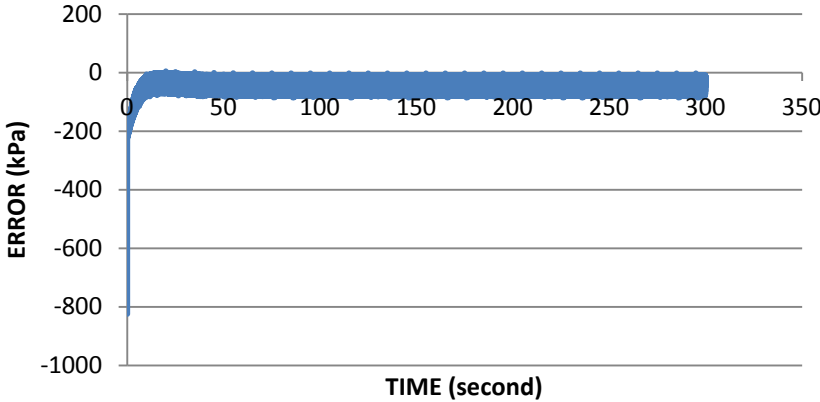
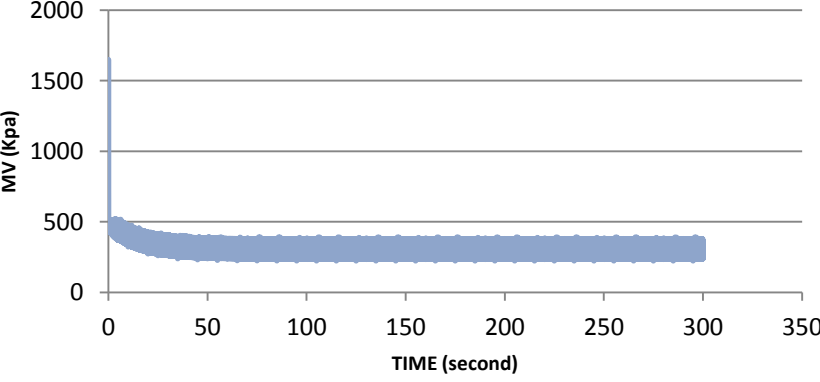
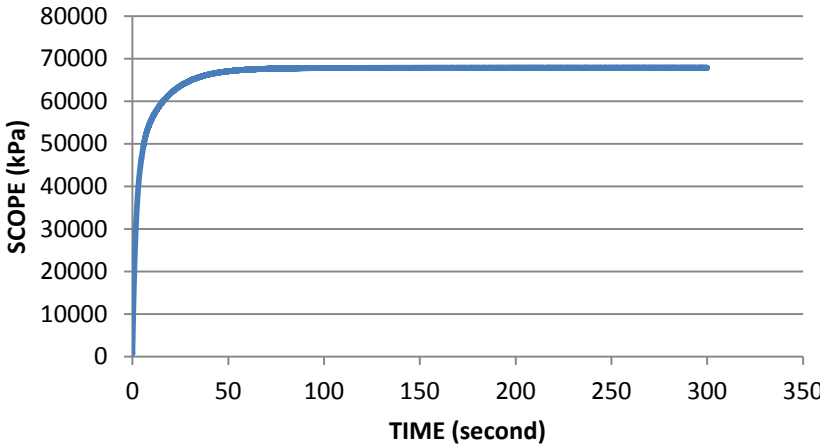
- Feedback Control

<p style="text-align: center;"><b>Error vs Time</b></p>  <p>ERROR (kPa)</p> <p>TIME (second)</p>	<p>Area of error =</p> <p>1.31E+36</p> <p>Stable at beginning at value of 0 and begin to decrease at negative value in short time</p>
<p style="text-align: center;"><b>MV vs Time</b></p>  <p>MV (kPa)</p> <p>TIME (second)</p>	<p>Stable at beginning at value of 0 and begin to decrease at negative value in short time</p>
<p style="text-align: center;"><b>Scope vs Time</b></p>  <p>SCOPE (kPa)</p> <p>TIME (second)</p>	<p>Stable at beginning at value of 0 and begin to increase at positive value in short time</p>

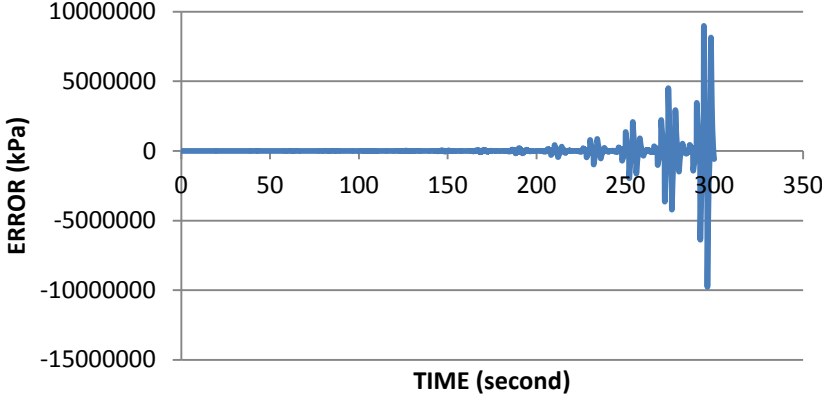
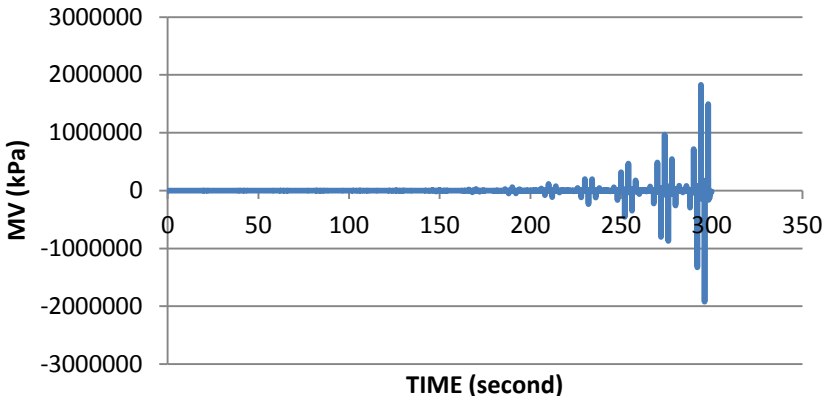
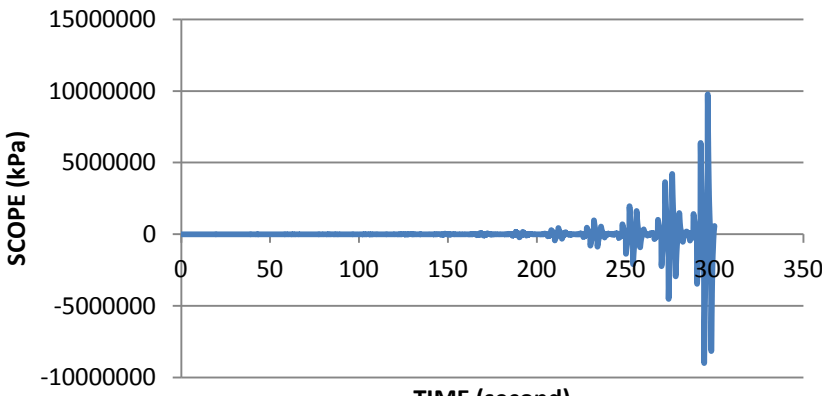
- Feedforward-feedback Control

<p style="text-align: center;"><b>Error vs Time</b></p>  <p>The graph shows the error signal over time. The y-axis is labeled 'ERROR (kPa)' and ranges from 0 to -2.5E+35. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The error signal is a blue line that remains at 0 until about 280 seconds, then drops vertically to -2.5E+35.</p>	<p>Area of error =</p> <p style="text-align: center;"><math>6.99E+35</math></p> <p>Stable at beginning at value of 0 and begin to decrease at negative value in short time</p>
<p style="text-align: center;"><b>MV vs Time</b></p>  <p>The graph shows the manipulated variable (MV) over time. The y-axis is labeled 'MV (kPa)' and ranges from 0 to -5E+35. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The MV signal is a blue line that remains at 0 until about 280 seconds, then drops vertically to -5E+35.</p>	<p>Stable at beginning at value of 0 and begin to decrease at negative value in short time</p>
<p style="text-align: center;"><b>Scope vs Time</b></p>  <p>The graph shows the scope signal over time. The y-axis is labeled 'SCOPE (kPa)' and ranges from -5E+34 to 2.5E+35. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The scope signal is a blue line that remains at 0 until about 280 seconds, then rises vertically to 2.5E+35.</p>	<p>Stable at beginning at value of 0 and begin to increase at positive value in short time</p>

- IMC Control

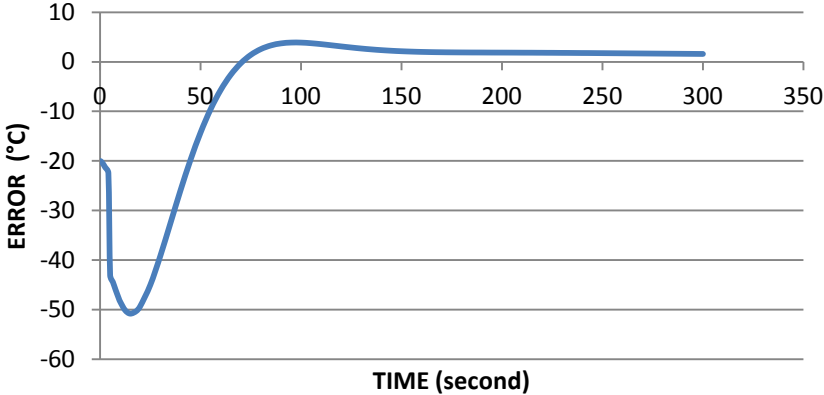
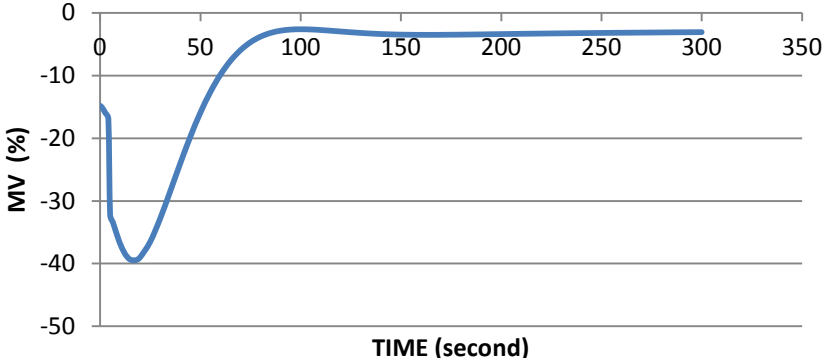
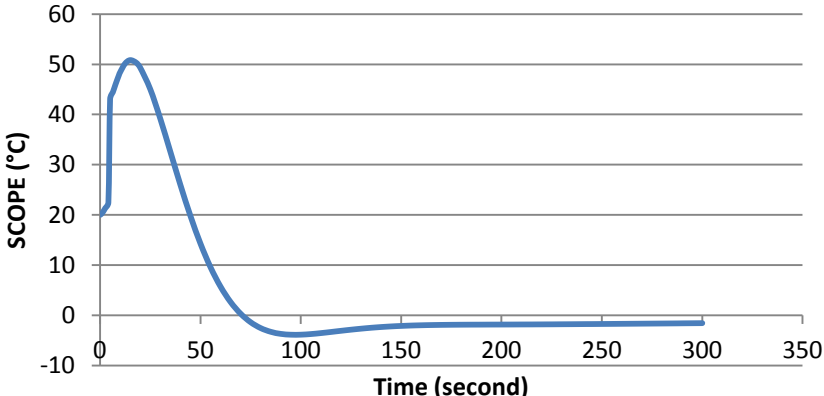
<p style="text-align: center;"><b>Error vs Time</b></p>  <p>Area of error: 10241.79</p> <p>Fluctuated at negative value</p>	
<p style="text-align: center;"><b>MV vs Time</b></p>  <p>Fluctuated at positive value</p>	
<p style="text-align: center;"><b>Scope vs Time</b></p>  <p>Stable but at a very high value</p>	

- Smith Control

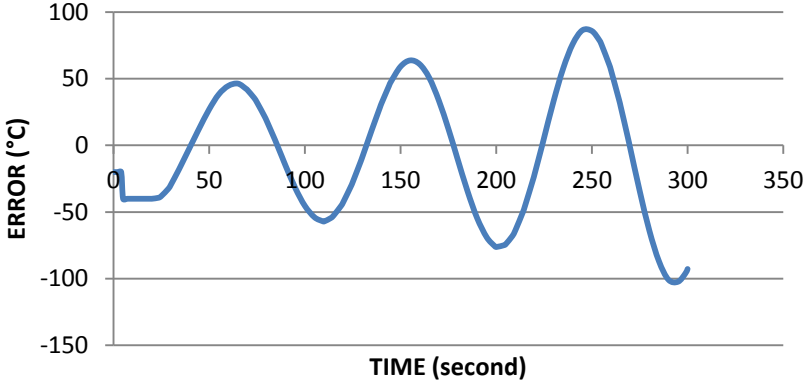
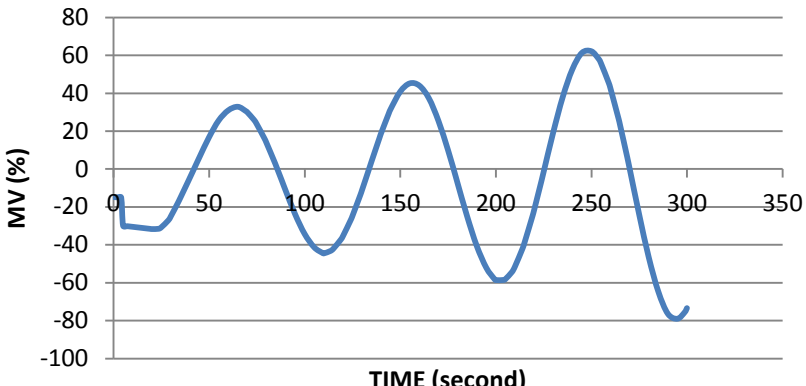
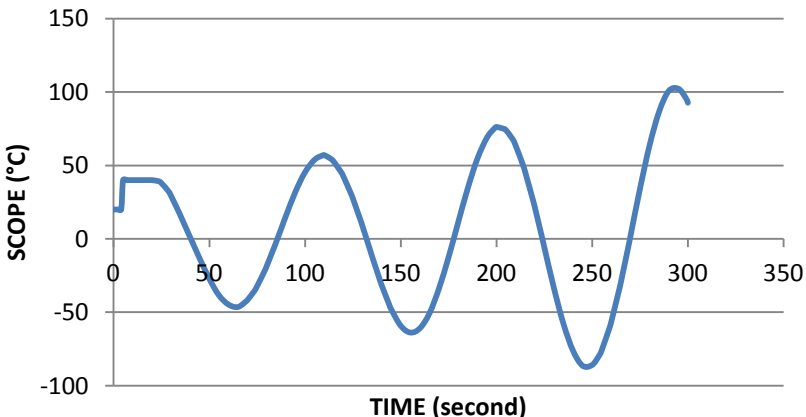
<h3 style="text-align: center;">Error vs Time</h3> 	<p>Area of error =</p> <p style="text-align: center;"><math>1.24\text{E}+06</math></p> <p>Stable but fluctuated at a very high value</p>
<h3 style="text-align: center;">MV vs Time</h3> 	<p>Stable but fluctuated at a very high value</p>
<h3 style="text-align: center;">Scope vs Time</h3> 	<p>Stable but fluctuated at a very high value</p>

7.1.6 TEMPERATURES

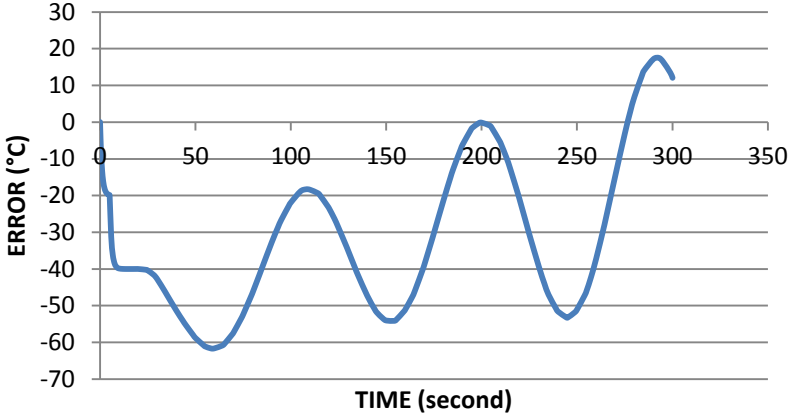
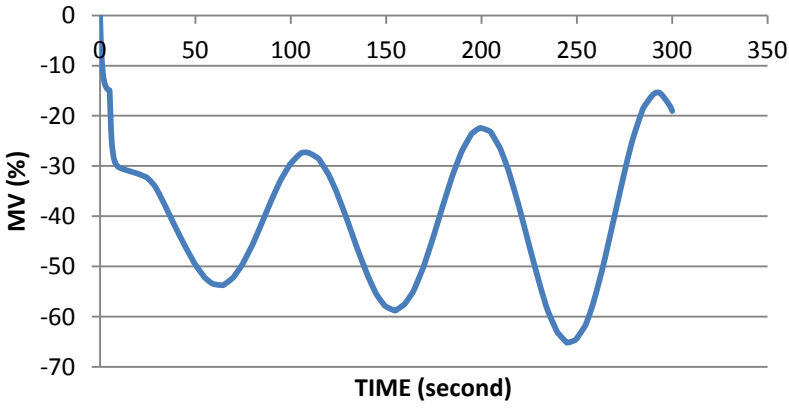
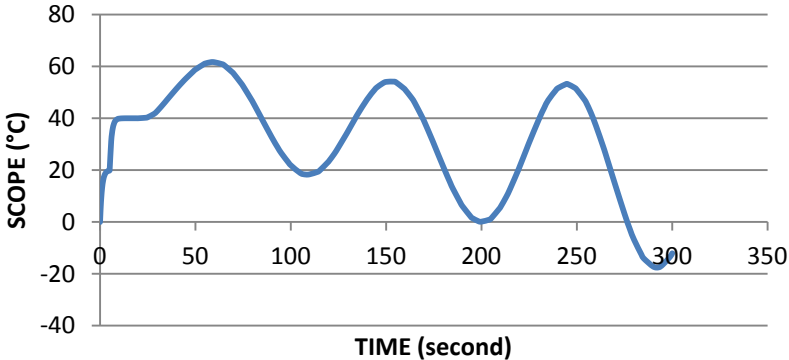
- Cascade Control

<p><b>Error vs Time</b></p>  <p>Area of error: 1441.73</p> <p>Fluctuated to negative value at the beginning and began to stable until the end</p>	
<p><b>MV vs Time</b></p>  <p>Fluctuated to negative value at the beginning and began to stable until the end</p>	
<p><b>Scope vs Time</b></p>  <p>Fluctuated at the beginning and begin to decrease to negative value until the end</p>	

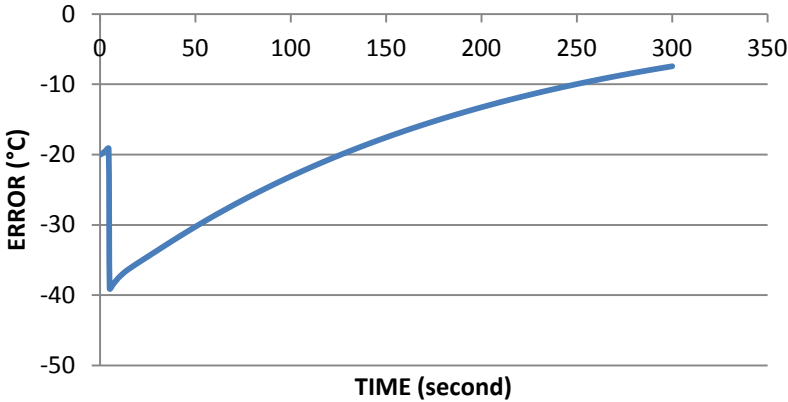
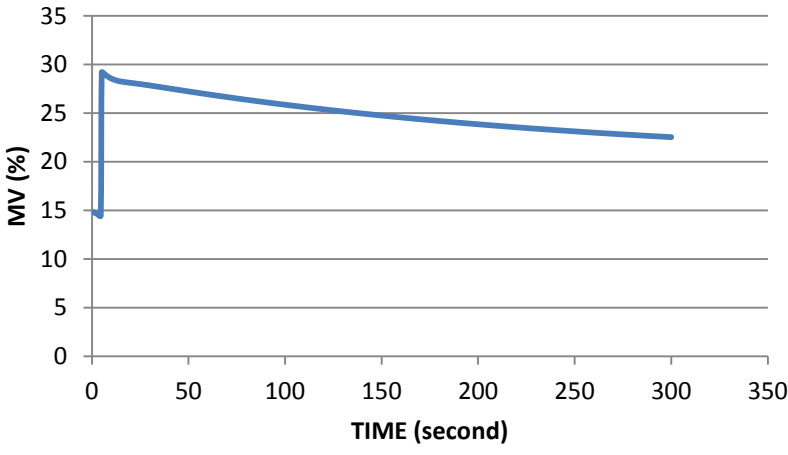
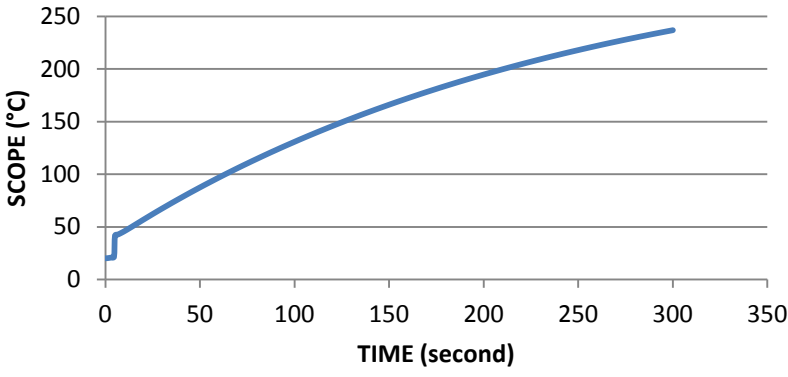
- Feedback Control

<h3>Error vs Time</h3>  <p>Y-axis: ERROR (°C) X-axis: TIME (second)</p>	<p>Area of error: 1633.74</p> <p>Fluctuated to negative value and unstable</p>
<h3>MV vs Time</h3>  <p>Y-axis: MV (%) X-axis: TIME (second)</p>	<p>Fluctuated to negative value and unstable</p>
<h3>Scope vs Time</h3>  <p>Y-axis: SCOPE (°C) X-axis: TIME (second)</p>	<p>Fluctuated to negative value and unstable</p>

- Feedforward-feedback Control

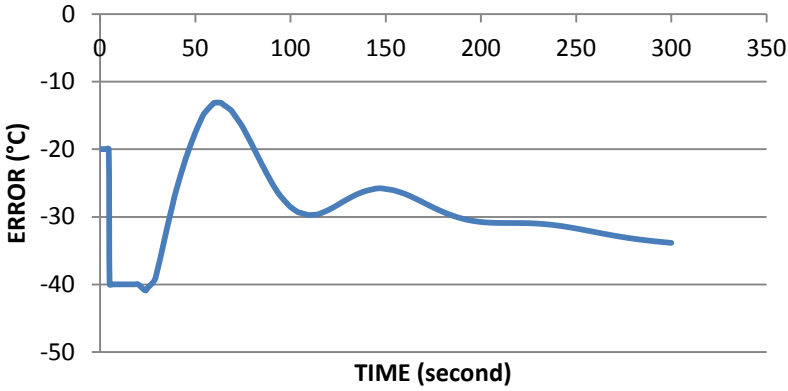
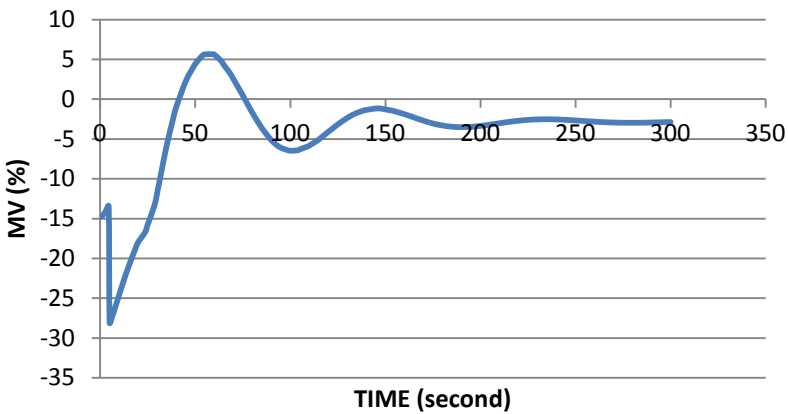
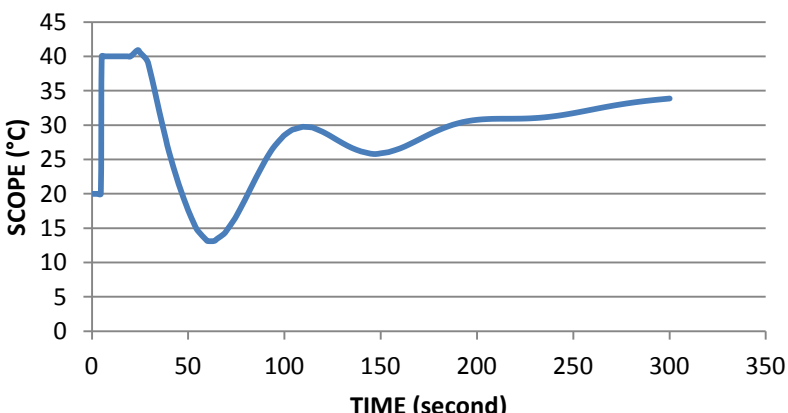
<h3>Error vs Time</h3>  <p>Area of error: 9440.15</p> <p>Fluctuated to negative value and unstable</p>	
<h3>MV vs Time</h3>  <p>Fluctuated to negative value and unstable</p>	
<h3>Scope vs Time</h3>  <p>Fluctuated to negative value and unstable</p>	

- IMC Control

<h3>Error vs Time</h3>  <p>The graph shows the error signal over 300 seconds. The y-axis is labeled 'ERROR (°C)' and ranges from -50 to 0. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The error starts at 0, drops sharply to approximately -40°C at 10 seconds, and then gradually increases back towards 0, reaching about -8°C at 300 seconds.</p>	<p>Area of error: 5753</p> <p>Fluctuated to negative value and unstable</p>
<h3>MV vs Time</h3>  <p>The graph shows the manipulated variable (MV) over 300 seconds. The y-axis is labeled 'MV (%)' and ranges from 0 to 35. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The MV starts at approximately 15%, jumps to about 29% at 10 seconds, and then slowly decreases to approximately 23% at 300 seconds.</p>	<p>Stable</p>
<h3>Scope vs Time</h3>  <p>The graph shows the process variable (SCOPE) over 300 seconds. The y-axis is labeled 'SCOPE (°C)' and ranges from 0 to 250. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The SCOPE starts at approximately 25°C, jumps to about 40°C at 10 seconds, and then steadily increases to approximately 240°C at 300 seconds.</p>	<p>Stable</p>



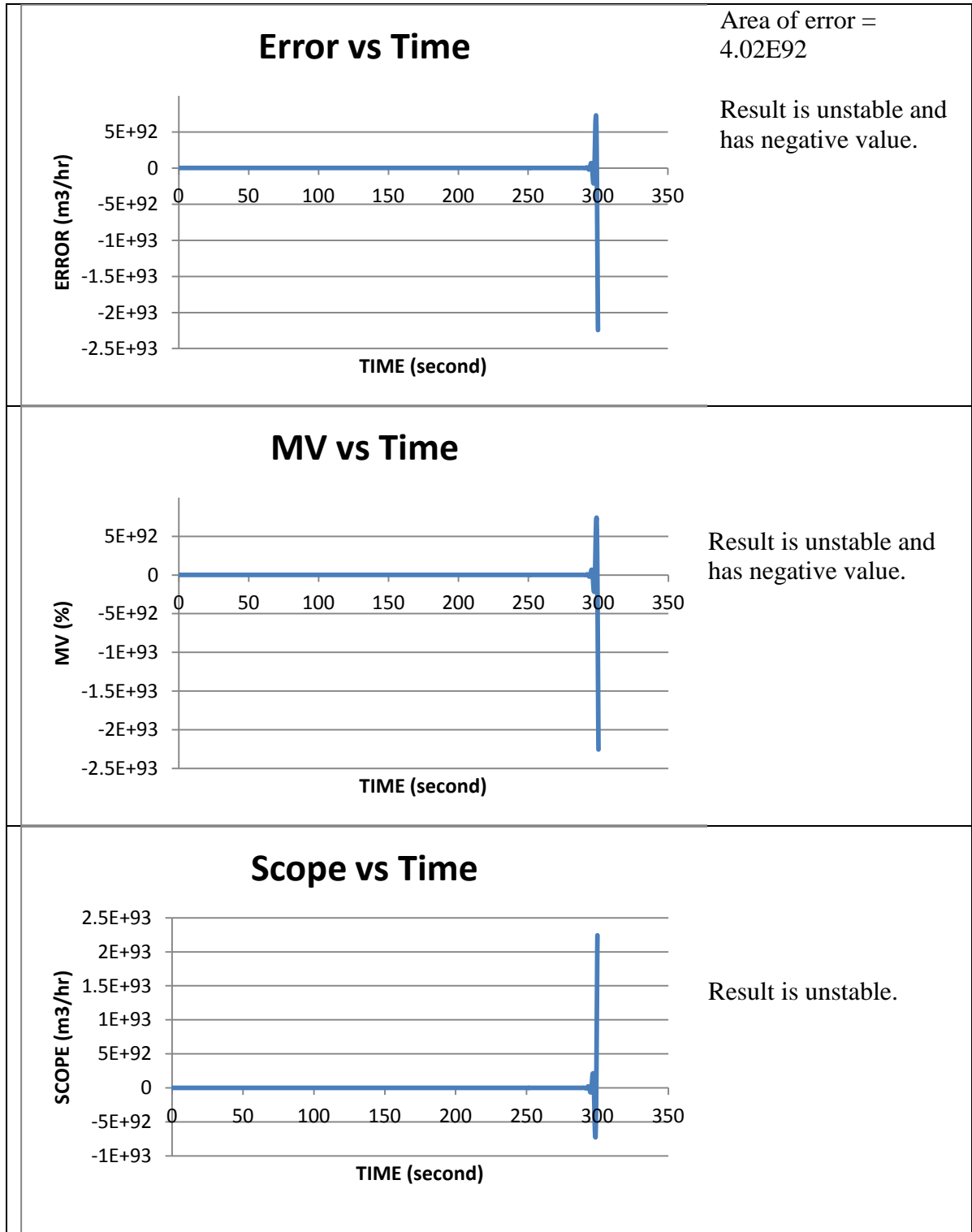
- Smith Control

<h3>Error vs Time</h3>  <p>Area of error: 8608.55</p> <p>Fluctuated to negative value</p>	
<h3>MV vs Time</h3>  <p>Fluctuated to negative value at beginning and begin to stable until the end</p>	
<h3>Scope vs Time</h3>  <p>Fluctuated but stable at positive value</p>	

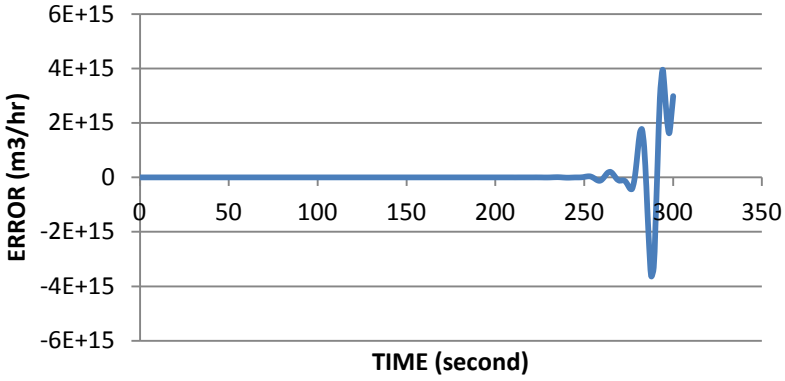
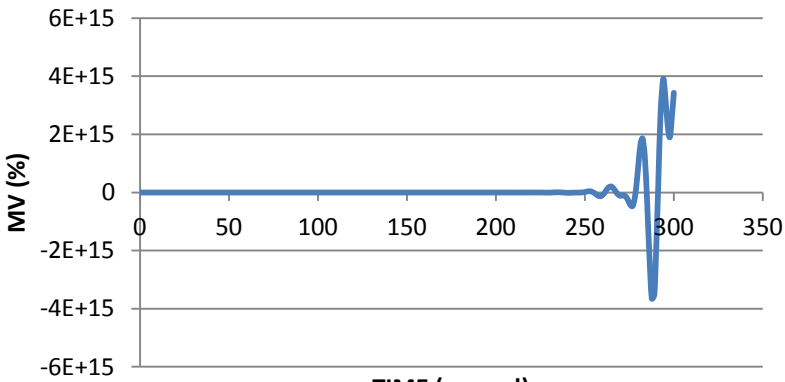
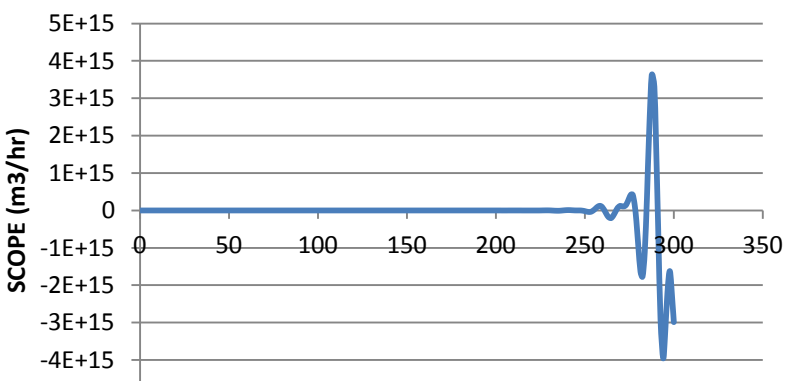
## 7.2 Step

### 7.2.1 FLOW1

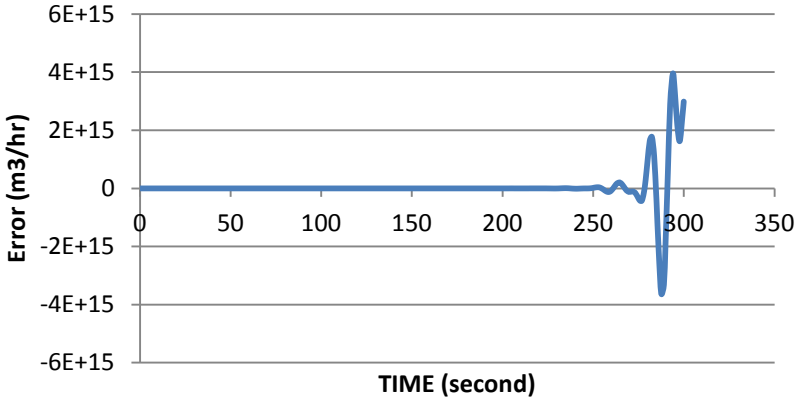
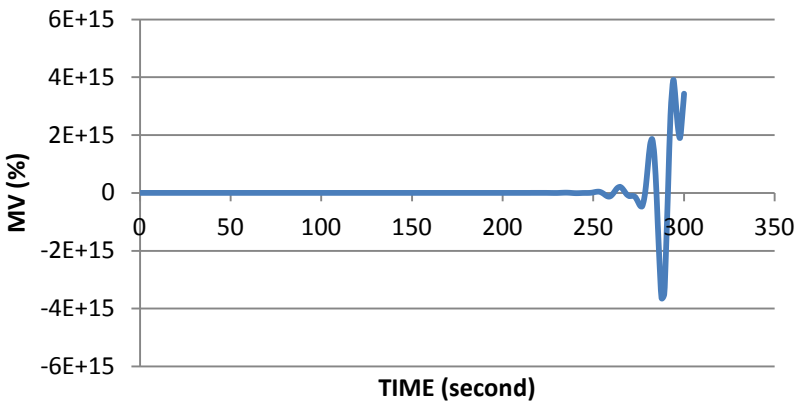
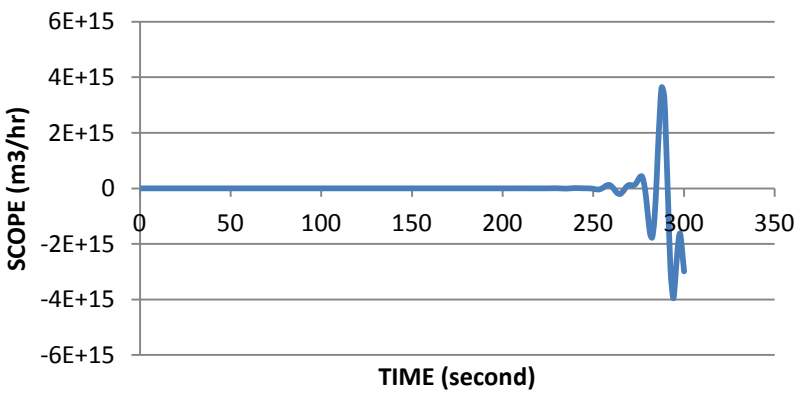
- Cascade Control



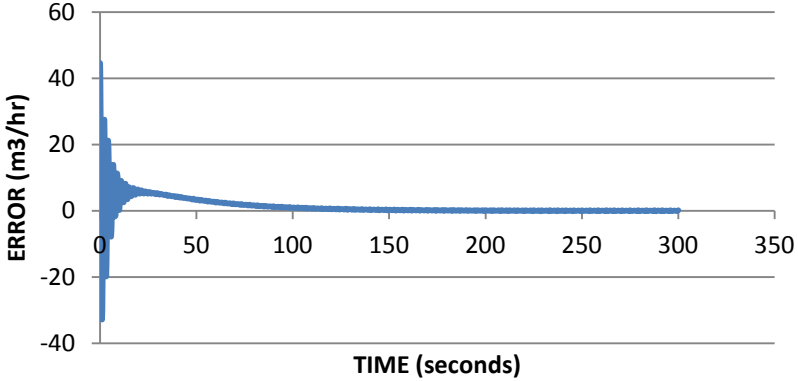
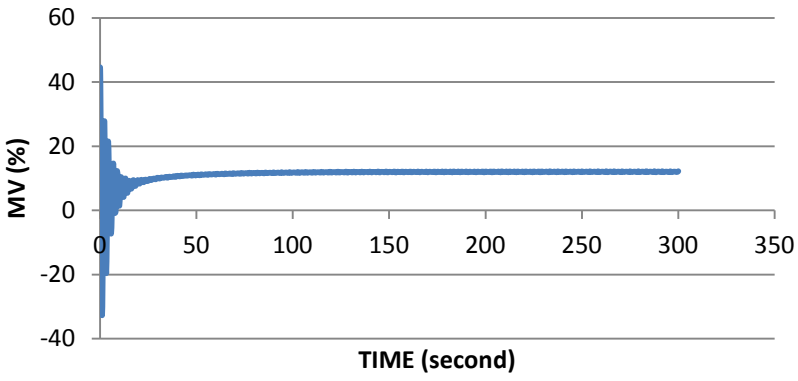
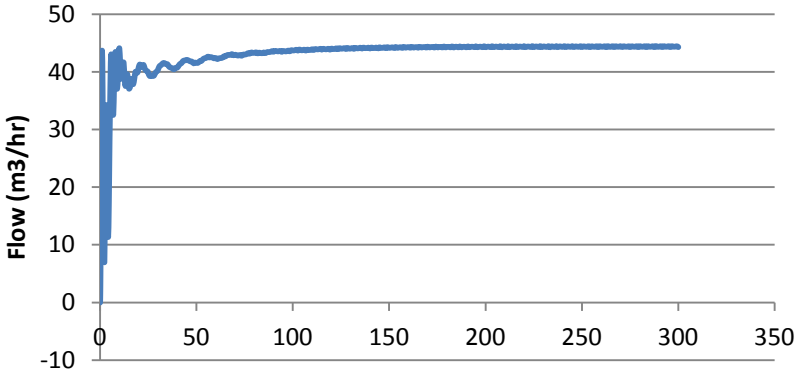
- Feedback Control

<h3>Error vs Time</h3>  <p>Y-axis: ERROR (m3/hr) ranging from -6E+15 to 6E+15. X-axis: TIME (second) ranging from 0 to 350.</p>	<p>Area of error: 1.3593e+16</p> <p>Maintained stable at the initial and begin to fluctuate at certain point.</p>
<h3>MV vs Time</h3>  <p>Y-axis: MV (%) ranging from -6E+15 to 6E+15. X-axis: TIME (second) ranging from 0 to 350.</p>	<p>Maintained stable at the initial and begin to fluctuate at certain point.</p>
<h3>Scope vs Time</h3>  <p>Y-axis: SCOPE (m3/hr) ranging from -5E+15 to 5E+15. X-axis: TIME (second) ranging from 0 to 350.</p>	<p>Maintained stable at the initial and begin to fluctuate at certain point.</p>

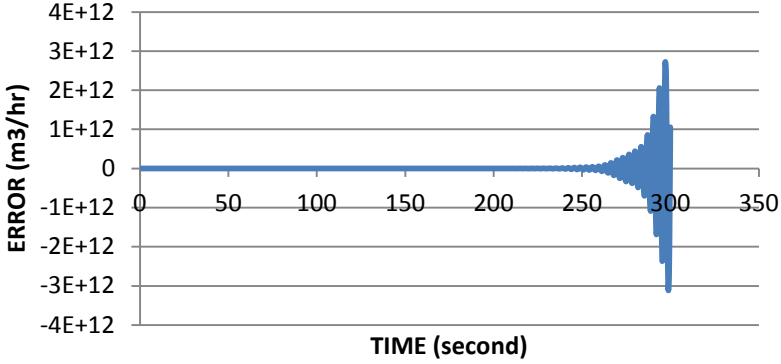
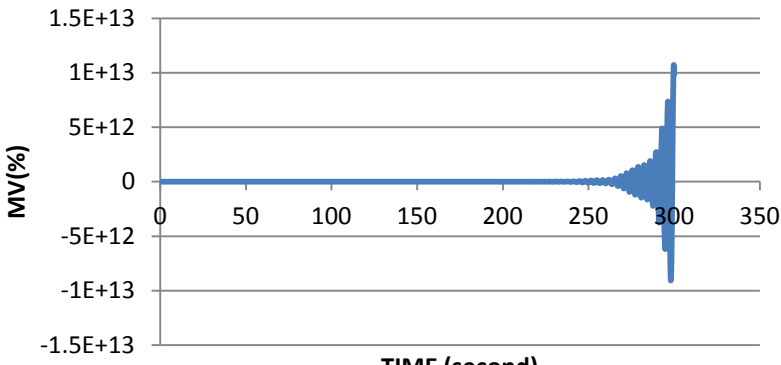
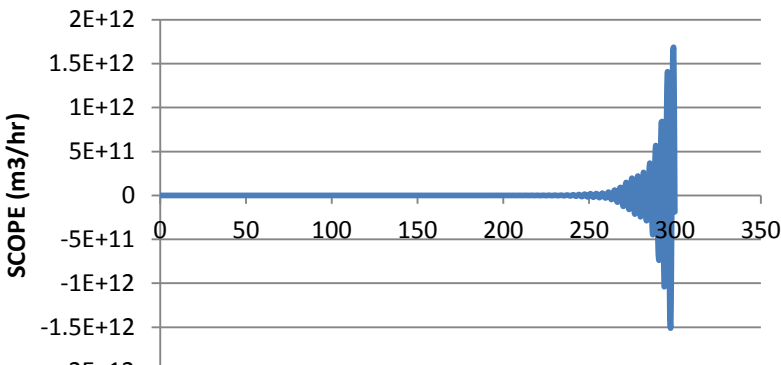
- Feedforward-feedback Control

<h3>Error vs Time</h3>  <p>The plot shows the error signal over time. The y-axis is labeled 'Error (m3/hr)' and ranges from -6E+15 to 6E+15. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The error signal is zero until about 250 seconds, where it begins to oscillate with increasing amplitude, reaching a peak of approximately 4E+15 m3/hr and a trough of approximately -4E+15 m3/hr by 300 seconds.</p>	<p>Area of error =</p> <p>1.36E+16</p> <p>Maintained stable at the initial and begin to fluctuate at certain point.</p>
<h3>MV vs Time</h3>  <p>The plot shows the manipulated variable (MV) over time. The y-axis is labeled 'MV (%)' and ranges from -6E+15 to 6E+15. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The MV signal is zero until about 250 seconds, where it begins to oscillate with increasing amplitude, reaching a peak of approximately 4E+15 % and a trough of approximately -4E+15 % by 300 seconds.</p>	<p>Maintained stable at the initial and begin to fluctuate at certain point.</p>
<h3>Scope vs Time</h3>  <p>The plot shows the scope signal over time. The y-axis is labeled 'SCOPE (m3/hr)' and ranges from -6E+15 to 6E+15. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The SCOPE signal is zero until about 250 seconds, where it begins to oscillate with increasing amplitude, reaching a peak of approximately 4E+15 m3/hr and a trough of approximately -4E+15 m3/hr by 300 seconds.</p>	<p>Maintained stable at the initial and begin to fluctuate at certain point.</p>

- IMC Control

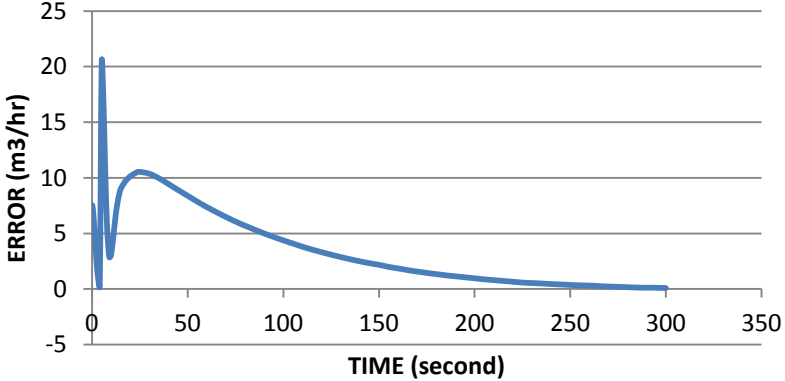
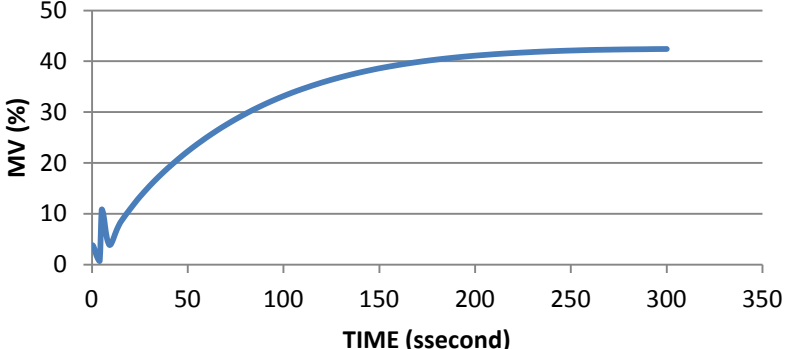
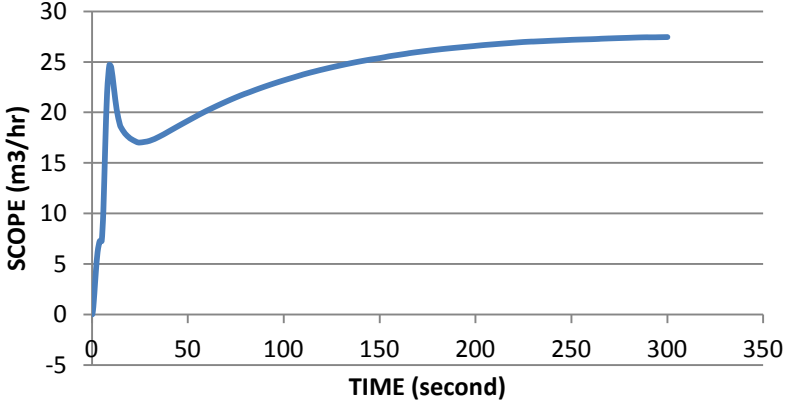
<p style="text-align: center;"><b>Error vs Time</b></p>  <p style="text-align: center;">TIME (seconds)</p>	<p>Area of error =</p> <p style="text-align: center;">367.392</p> <p>Fluctuated at the beginning and then maintained stable until the end.</p>
<p style="text-align: center;"><b>MV vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Fluctuated at the beginning and then maintained stable until the end.</p>
<p style="text-align: center;"><b>Flow vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Fluctuated at the beginning and then maintained stable until the end.</p>

- Smith Control

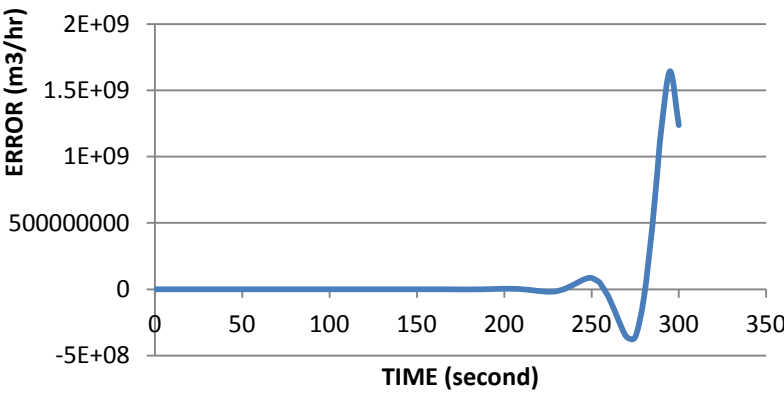
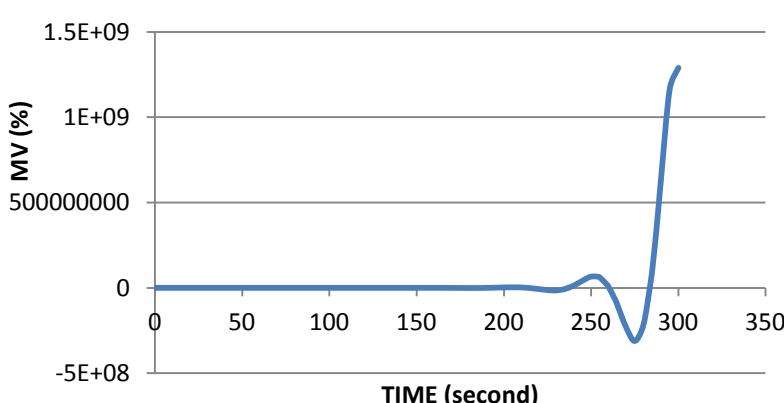
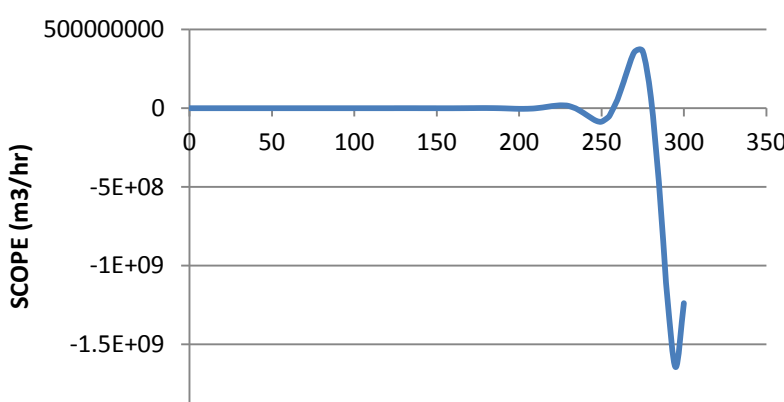
<h3>Error vs Time</h3>  <p>Y-axis: ERROR (m3/hr) ranging from -4E+12 to 4E+12. X-axis: TIME (second) ranging from 0 to 350.</p>	<p>Area of error = -1.74E+12</p> <p>Maintained stable at the beginning and begin to fluctuate at certain point.</p>
<h3>MV vs Time</h3>  <p>Y-axis: MV(%) ranging from -1.5E+13 to 1.5E+13. X-axis: TIME (second) ranging from 0 to 350.</p>	<p>Maintained stable at the beginning and begin to fluctuate at certain point.</p>
<h3>Scope vs Time</h3>  <p>Y-axis: SCOPE (m3/hr) ranging from -2E+12 to 2E+12. X-axis: TIME (second) ranging from 0 to 350.</p>	<p>Maintained stable at the beginning and begin to fluctuate at certain point.</p>

7.2.2 FLOW2

- Cascade Control

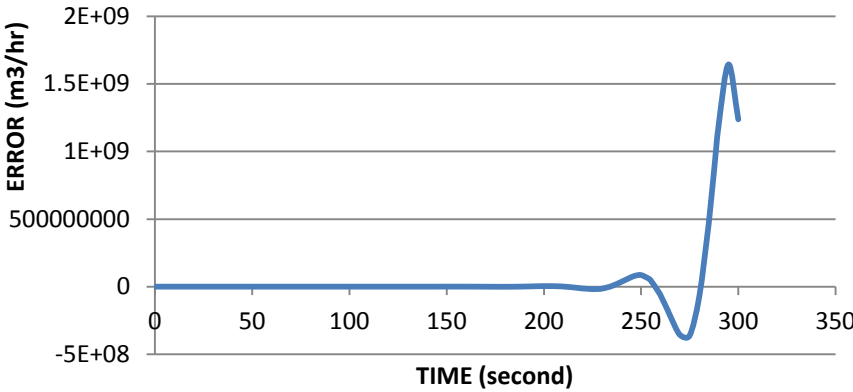
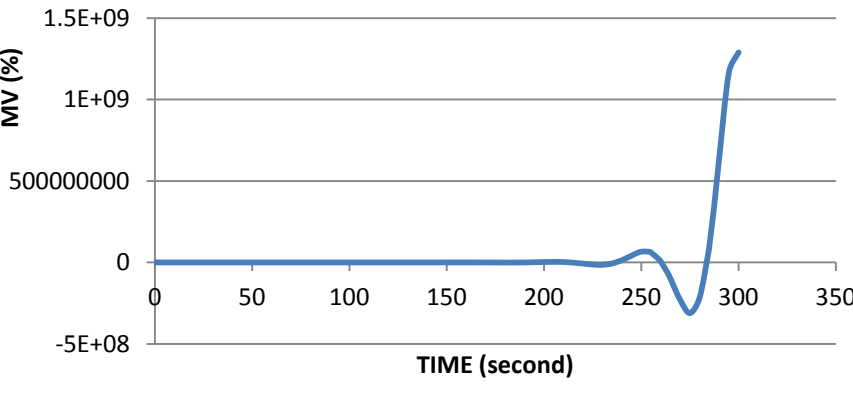
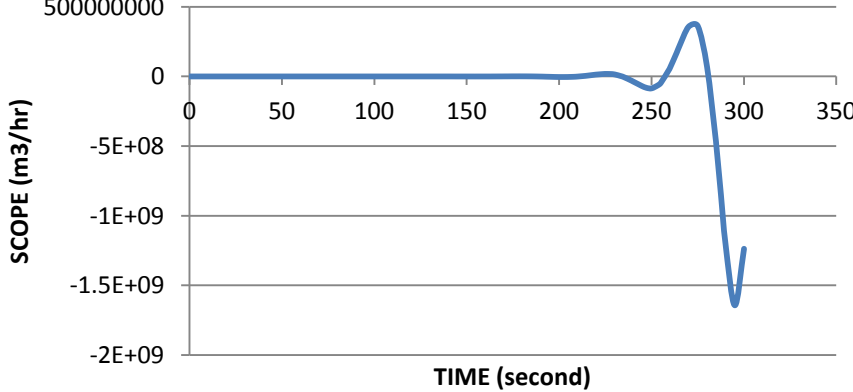
<p><b>Error vs Time</b></p>  <p>Area of error =</p> <p>1.03E+03</p> <p>Fluctuated at the beginning and then maintained stable until the end.</p>	
<p><b>MV vs Time</b></p>  <p>Fluctuated at the beginning and then maintained stable until the end.</p>	
<p><b>Scope vs Time</b></p>  <p>Fluctuated at the beginning and then maintained stable until the end.</p>	

- Feedback Control

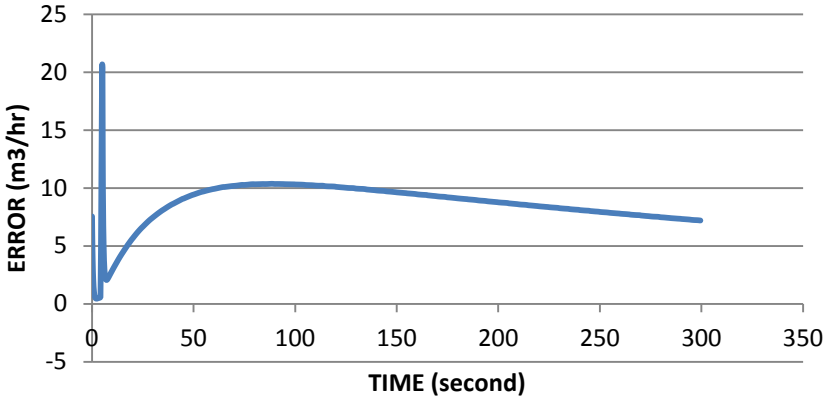
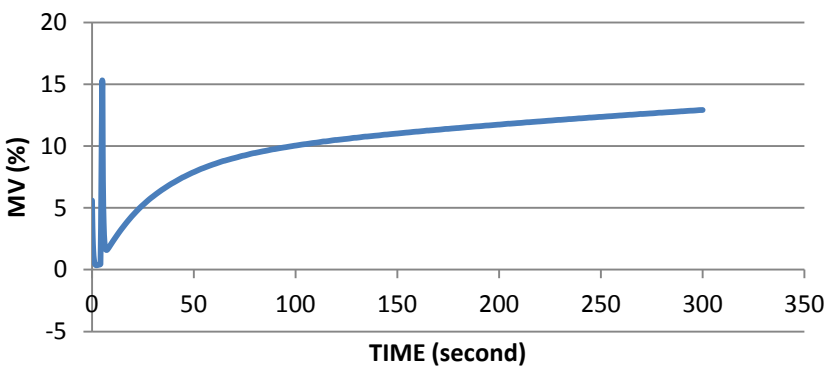
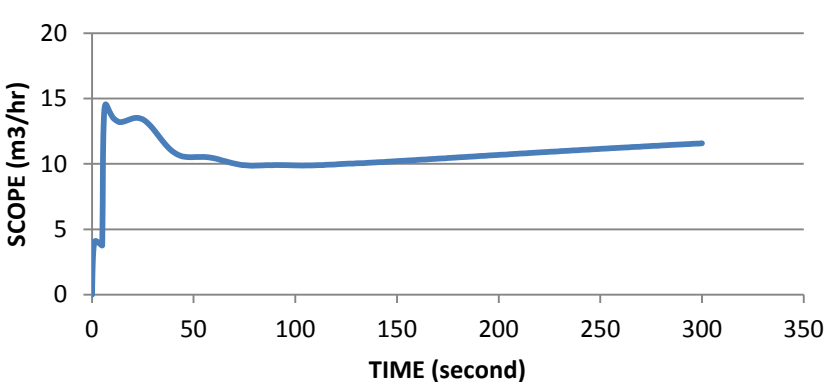
<h3>Error vs Time</h3>  <p>The plot shows the error signal over time. The y-axis is labeled 'ERROR (m3/hr)' and ranges from -5E+08 to 2E+09. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The error is zero until approximately 250 seconds, where it exhibits a small positive peak followed by a small negative peak. At 300 seconds, the error spikes sharply to approximately 1.5E+09 m3/hr.</p>	<p>Area of error = 1.55E+10 Not stable</p>
<h3>MV vs Time</h3>  <p>The plot shows the manipulated variable (MV) over time. The y-axis is labeled 'MV (%)' and ranges from -5E+08 to 1.5E+09. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The MV is zero until approximately 250 seconds, where it exhibits a small positive peak followed by a small negative peak. At 300 seconds, the MV spikes sharply to approximately 1.5E+09 %.</p>	<p>Not stable</p>
<h3>Scope vs Time</h3>  <p>The plot shows the scope signal over time. The y-axis is labeled 'SCOPE (m3/hr)' and ranges from -2E+09 to 500000000. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The scope is zero until approximately 250 seconds, where it exhibits a small positive peak followed by a small negative peak. At 300 seconds, the scope spikes sharply to approximately 500000000 m3/hr.</p>	<p>Not stable</p>



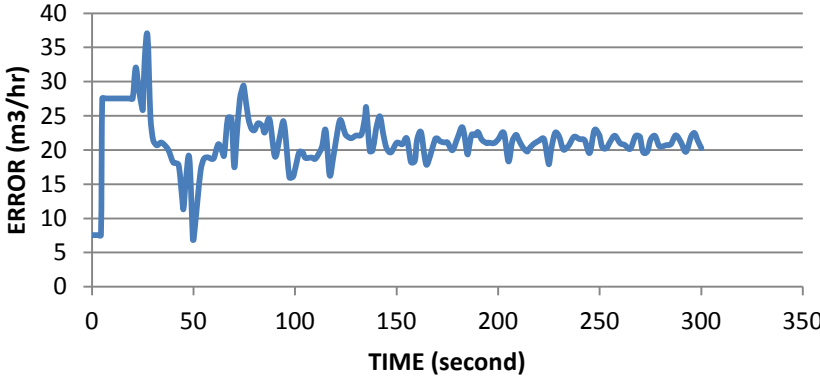
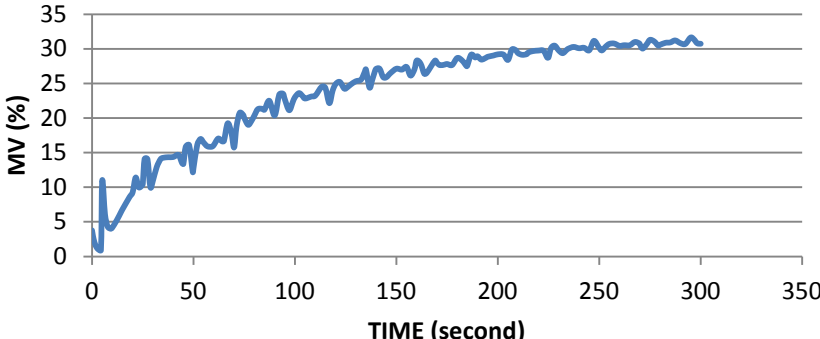
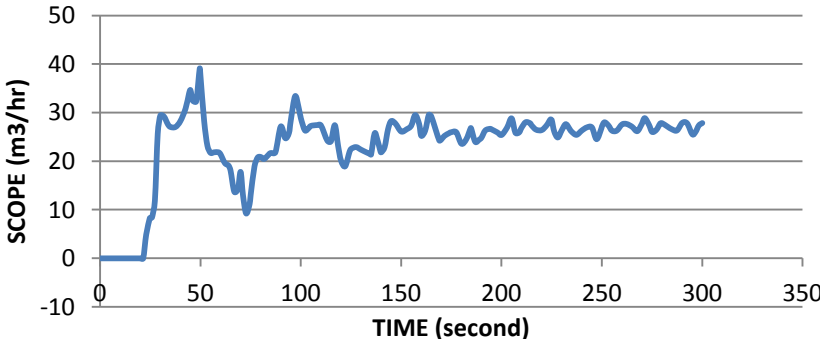
- Feedforward-feedback

<h3>Error vs Time</h3>  <p>The graph shows the error signal over time. The y-axis is labeled 'ERROR (m3/hr)' and ranges from -5E+08 to 2E+09. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The error is stable at zero until approximately 250 seconds, where it exhibits a small peak. At 300 seconds, there is a sharp, large positive spike reaching about 1.5E+09 m3/hr.</p>	<p>Area of error = 1.55E+10</p> <p>Not stable</p>
<h3>MV vs Time</h3>  <p>The graph shows the manipulated variable (MV) over time. The y-axis is labeled 'MV (%)' and ranges from -5E+08 to 1.5E+09. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The MV is stable at zero until approximately 250 seconds, where it exhibits a small peak. At 300 seconds, there is a sharp, large positive spike reaching about 1.2E+09 %.</p>	<p>Not stable</p>
<h3>Scope vs Time</h3>  <p>The graph shows the scope signal over time. The y-axis is labeled 'SCOPE (m3/hr)' and ranges from -2E+09 to 500000000. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The scope is stable at zero until approximately 250 seconds, where it exhibits a small peak. At 280 seconds, it reaches a peak of about 3E+08 m3/hr, then drops sharply to a minimum of about -1.5E+09 m3/hr at 300 seconds.</p>	<p>Not stable</p>

- IMC Control

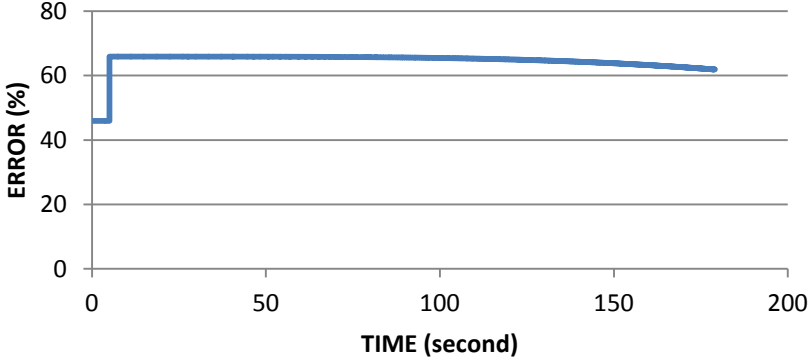
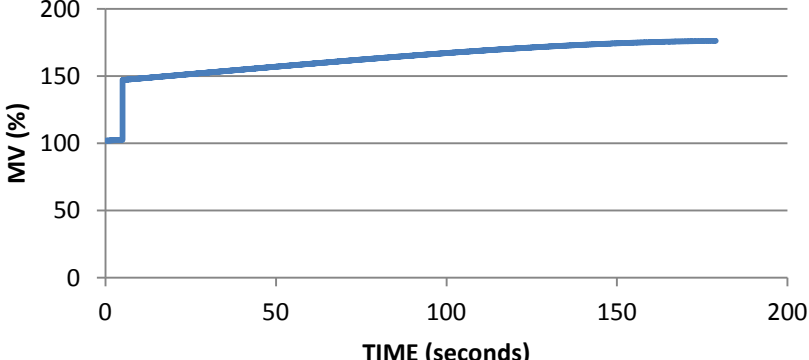
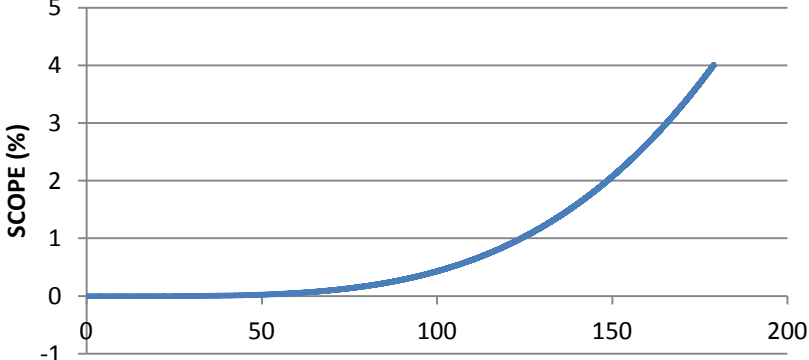
<p style="text-align: center;"><b>Error vs Time</b></p> 	<p>Area of error =</p> <p>2.58E+03</p> <p>Fluctuated at the beginning and then maintained stable until the end</p>
<p style="text-align: center;"><b>MV vs Time</b></p> 	<p>Fluctuated at the beginning and then maintained stable until the end</p>
<p style="text-align: center;"><b>Scope vs Time</b></p> 	<p>Fluctuated at the beginning and then maintained stable until the end</p>

- Smith Control

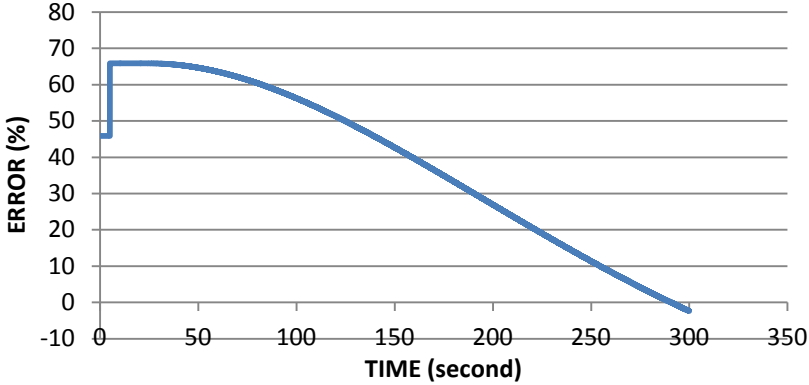
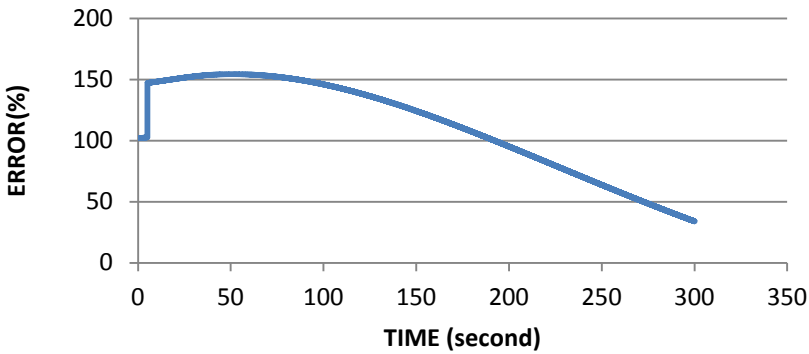
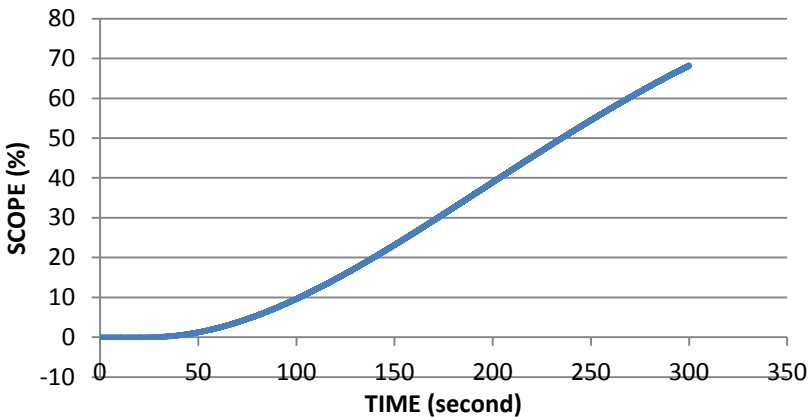
<p style="text-align: center;"><b>Error vs Time</b></p> 	<p>Area of error =</p> <p style="text-align: center;"><math>6.37\text{E}+03</math></p> <p>Fluctuating and unstable</p>
<p style="text-align: center;"><b>MV vs Time</b></p> 	<p>Fluctuating and unstable</p>
<p style="text-align: center;"><b>Scope vs Time</b></p> 	<p>Fluctuating and unstable</p>

7.2.3 LEVEL 1

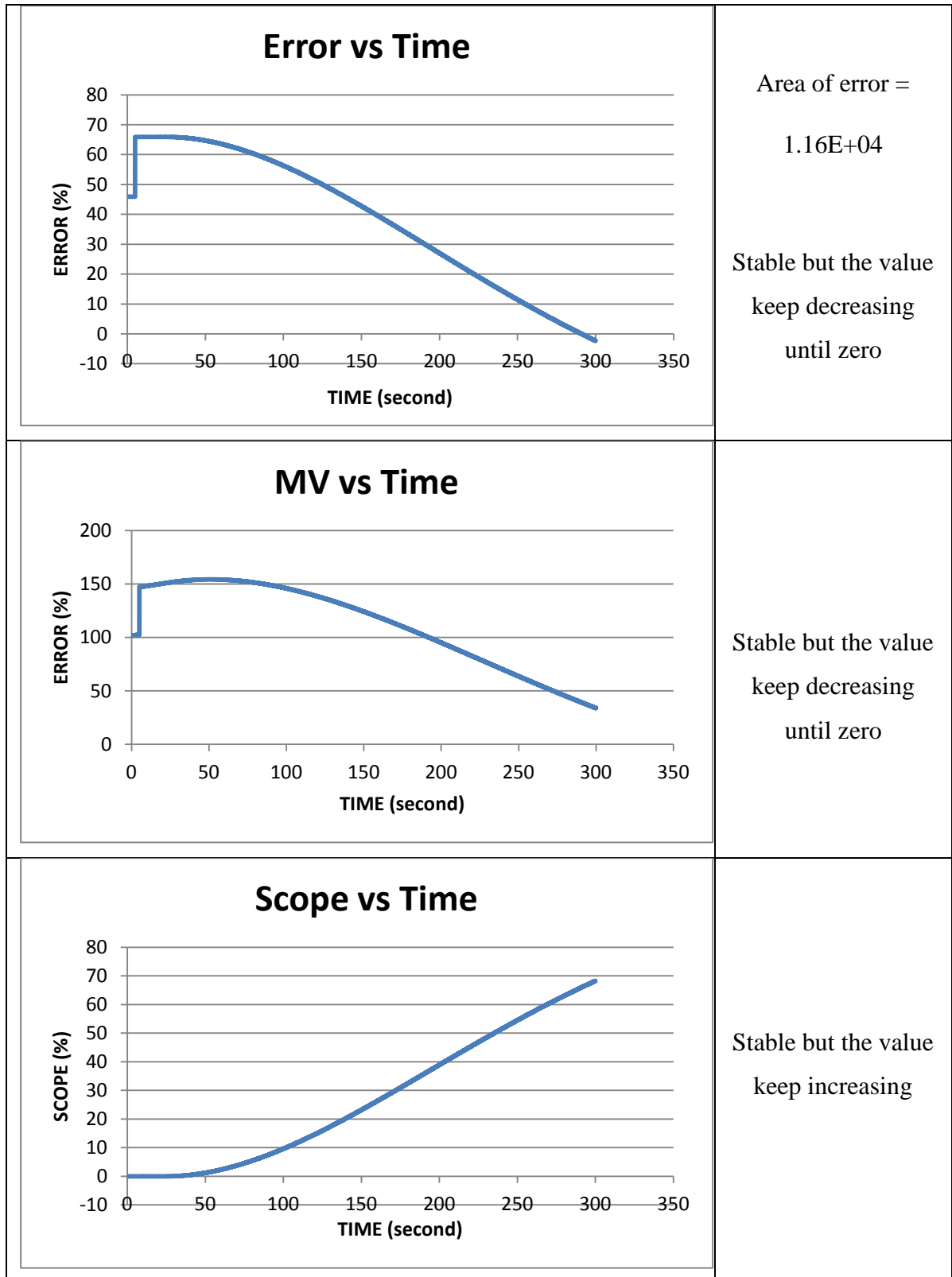
- Cascade Control

<p><b>Error vs Time</b></p>  <p>Area of error = 1.80E+04 Stable</p>	
<p><b>MV vs Time</b></p>  <p>Stable</p>	
<p><b>Scope vs Time</b></p>  <p>Stable</p>	

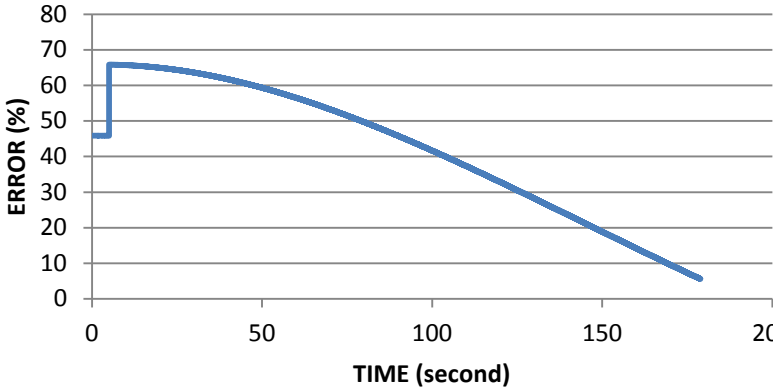
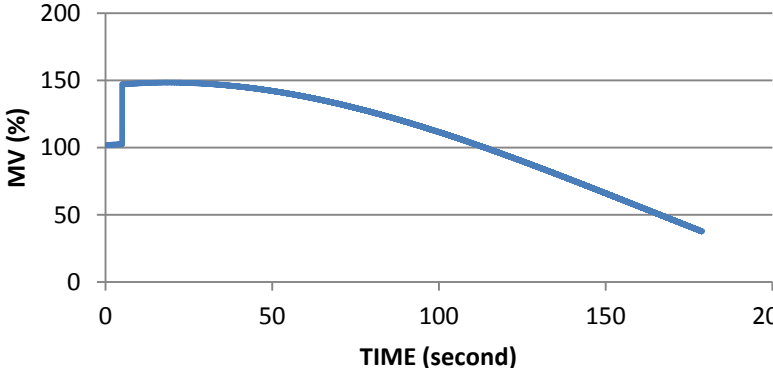
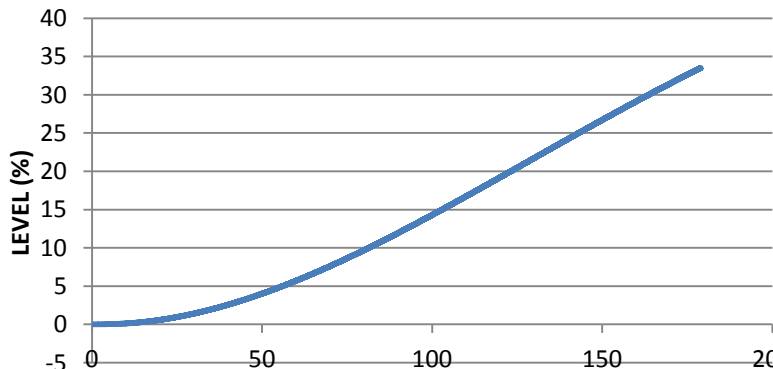
- Feedback Control

<h3>Error vs Time</h3>  <p>The graph shows the error percentage over time. The y-axis is labeled 'ERROR (%)' and ranges from -10 to 80. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The error starts at approximately 65% at 0 seconds, drops slightly to about 60% at 10 seconds, and then decreases steadily to 0% at 300 seconds.</p>	<p>Area of error =</p> <p>1.16E+04</p> <p>Stable but the value keep decreasing until zero</p>
<h3>MV vs Time</h3>  <p>The graph shows the error percentage over time. The y-axis is labeled 'ERROR (%)' and ranges from 0 to 200. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The error starts at 100% at 0 seconds, rises to a peak of approximately 155% at 60 seconds, and then decreases steadily to approximately 35% at 300 seconds.</p>	<p>Stable but the value keep decreasing until zero</p>
<h3>Scope vs Time</h3>  <p>The graph shows the scope percentage over time. The y-axis is labeled 'SCOPE (%)' and ranges from -10 to 80. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The scope starts at 0% at 0 seconds and increases steadily to approximately 68% at 300 seconds.</p>	<p>Stable but the value keep increasing</p>

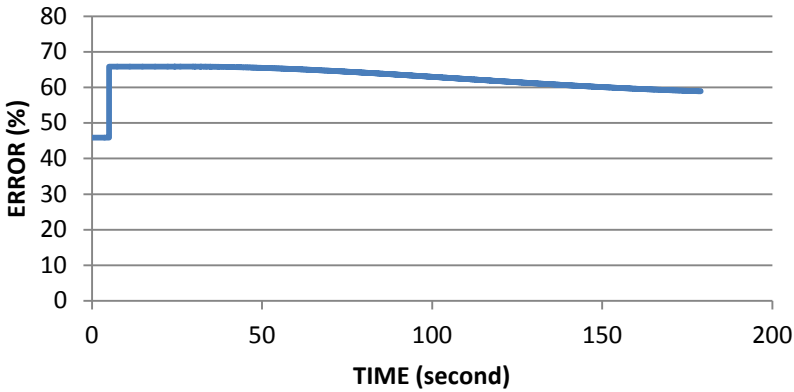
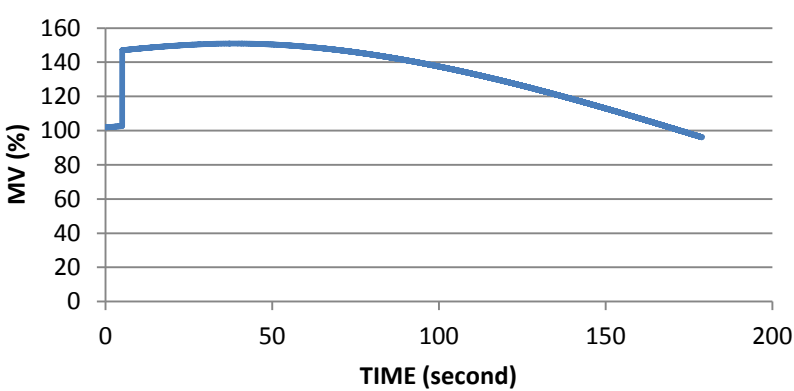
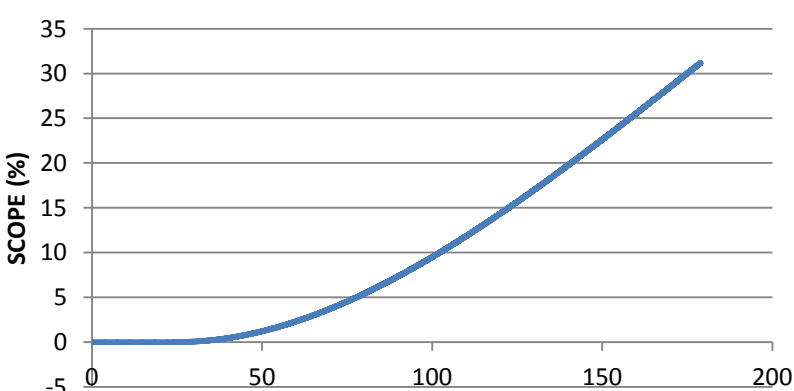
- Feedforward-feedback Control



- IMC Control

<h3>Error vs Time</h3>  <p>The graph shows the error percentage over time. The y-axis is labeled 'ERROR (%)' and ranges from 0 to 80. The x-axis is labeled 'TIME (second)' and ranges from 0 to 200. The error starts at 0, jumps to approximately 65% at 5 seconds, and then gradually decreases to about 5% at 180 seconds.</p>	<p>Area of error = 5.52E+03</p> <p>Stable but the value keep decreasing until zero</p>
<h3>MV vs Time</h3>  <p>The graph shows the MV percentage over time. The y-axis is labeled 'MV (%)' and ranges from 0 to 200. The x-axis is labeled 'TIME (second)' and ranges from 0 to 200. The MV starts at 100, jumps to approximately 150 at 5 seconds, and then gradually decreases to about 40% at 180 seconds.</p>	<p>Stable but then the value keep decreasing until zero</p>
<h3>Level vs Time</h3>  <p>The graph shows the level percentage over time. The y-axis is labeled 'LEVEL (%)' and ranges from -5 to 40. The x-axis is labeled 'TIME (second)' and ranges from 0 to 200. The level starts at 0 and increases steadily to about 35% at 180 seconds.</p>	<p>Stable but then the value keep increasing</p>

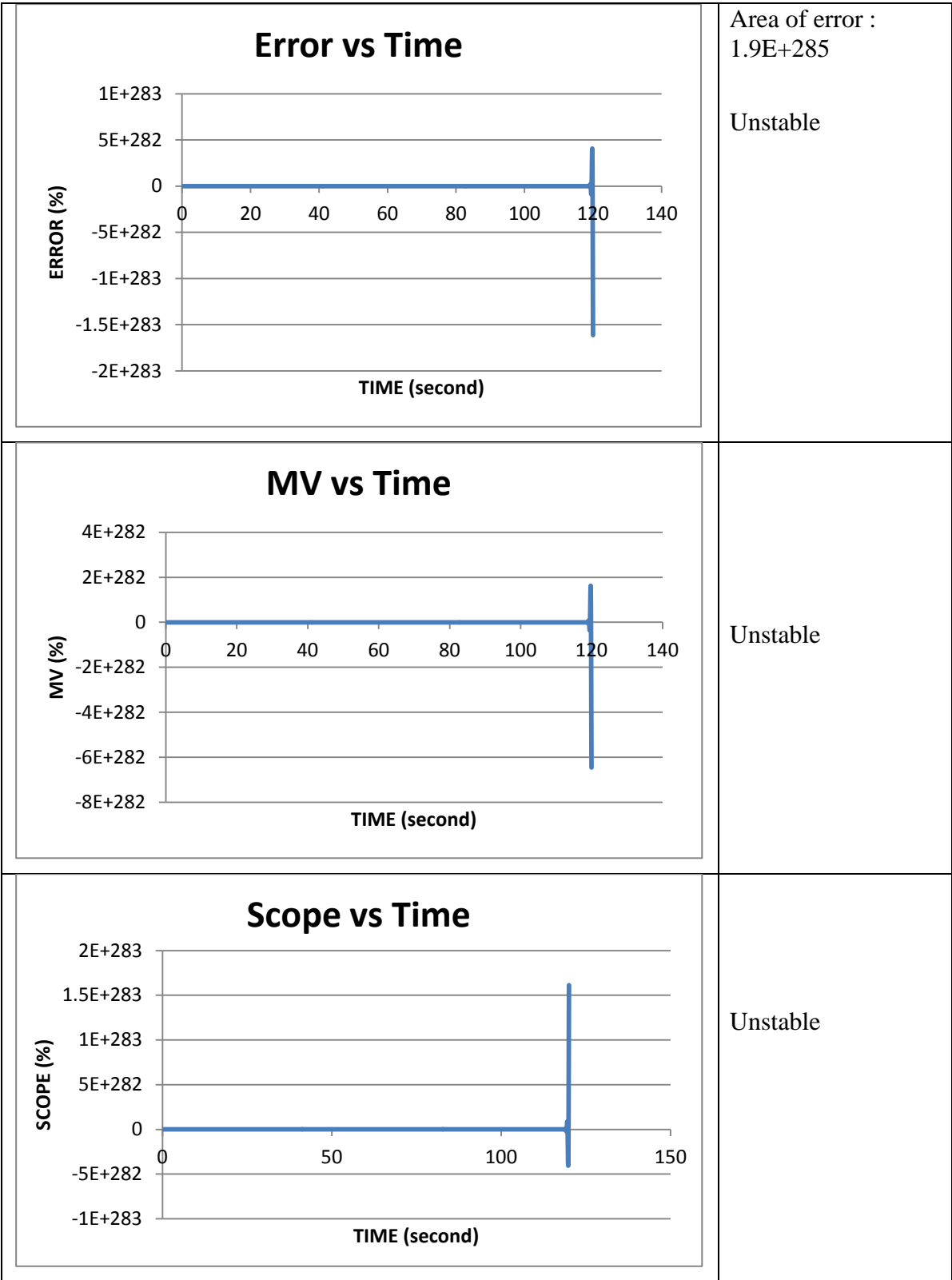
- Smith Control

<h3>Error vs Time</h3>  <p>The graph shows the error percentage over time. The y-axis is labeled 'ERROR (%)' and ranges from 0 to 80. The x-axis is labeled 'TIME (second)' and ranges from 0 to 200. The error signal starts at 0, jumps to approximately 65% at 5 seconds, and then slowly decreases to about 58% by 180 seconds.</p>	<p>Area of error =</p> <p>1.84E+04</p> <p>Stable</p>
<h3>MV vs Time</h3>  <p>The graph shows the manipulated variable (MV) percentage over time. The y-axis is labeled 'MV (%)' and ranges from 0 to 160. The x-axis is labeled 'TIME (second)' and ranges from 0 to 200. The MV starts at 100%, jumps to approximately 150% at 5 seconds, peaks slightly, and then slowly decreases to about 95% by 180 seconds.</p>	<p>Stable</p>
<h3>Scope vs Time</h3>  <p>The graph shows the scope percentage over time. The y-axis is labeled 'SCOPE (%)' and ranges from -5 to 35. The x-axis is labeled 'TIME (second)' and ranges from 0 to 200. The scope starts at 0% and increases steadily to approximately 32% by 180 seconds.</p>	<p>Maintained stable and then the value keep increasing</p>

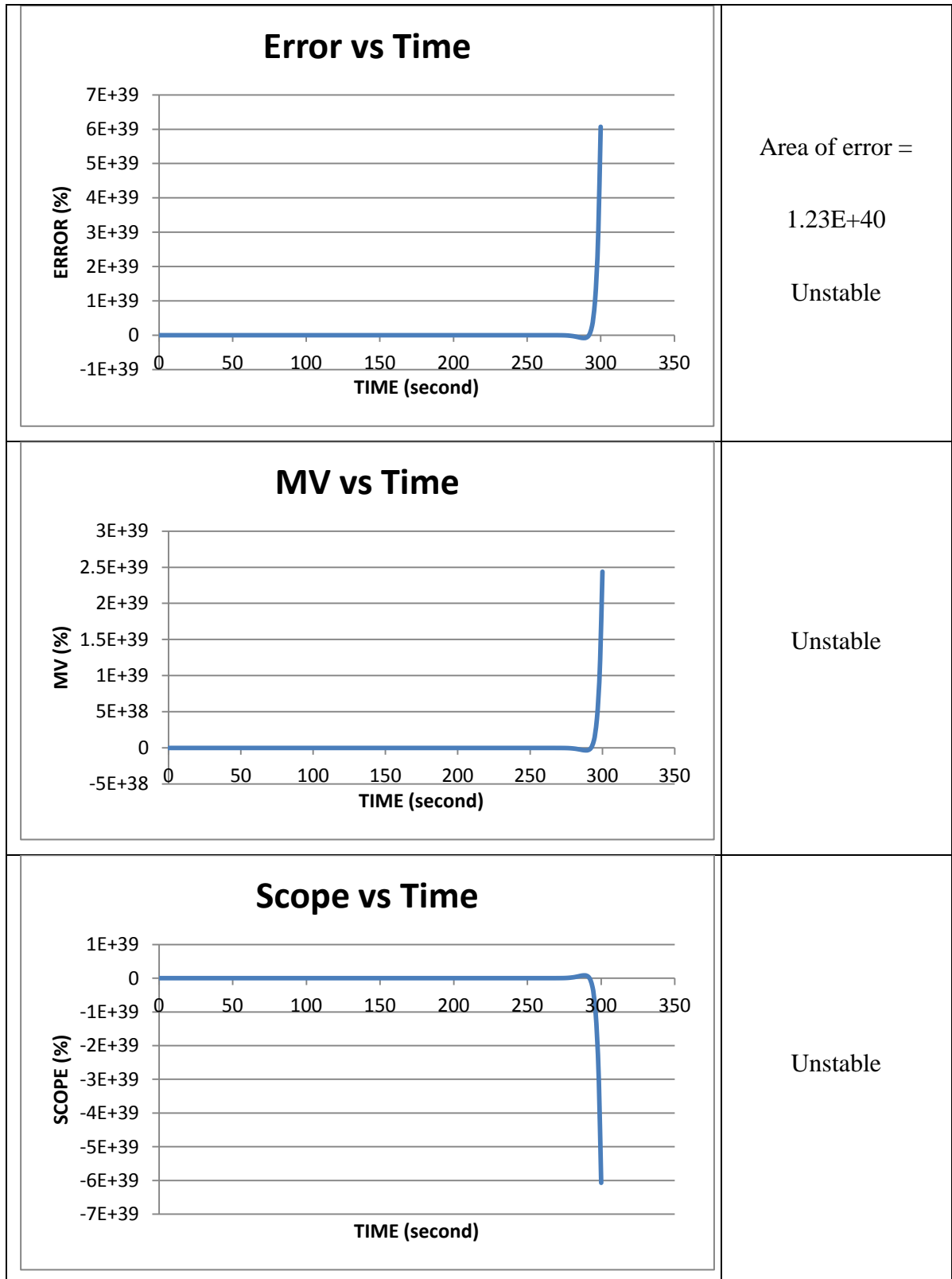


### 7.2.4 LEVEL 2

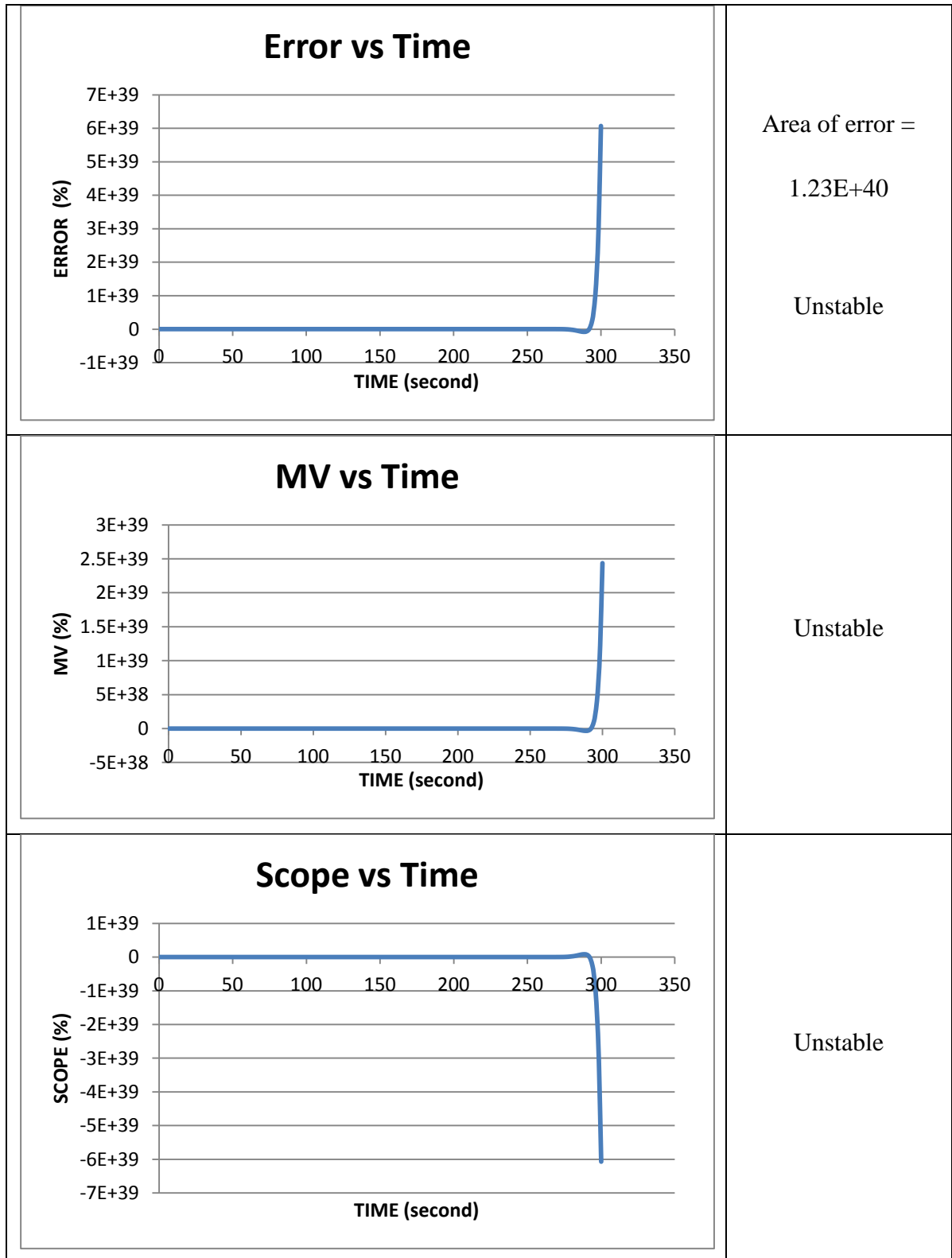
- Cascade Control



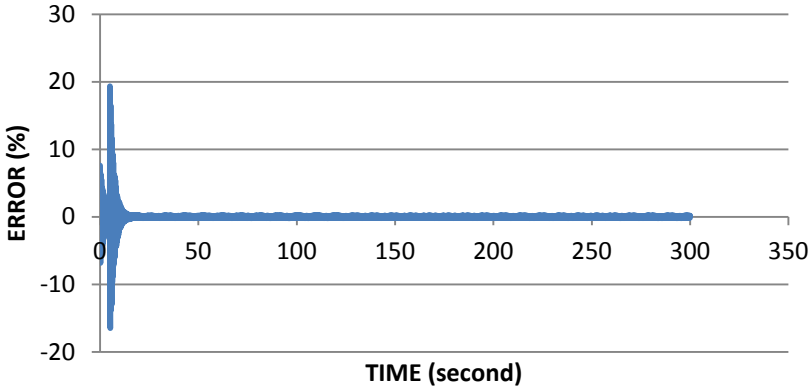
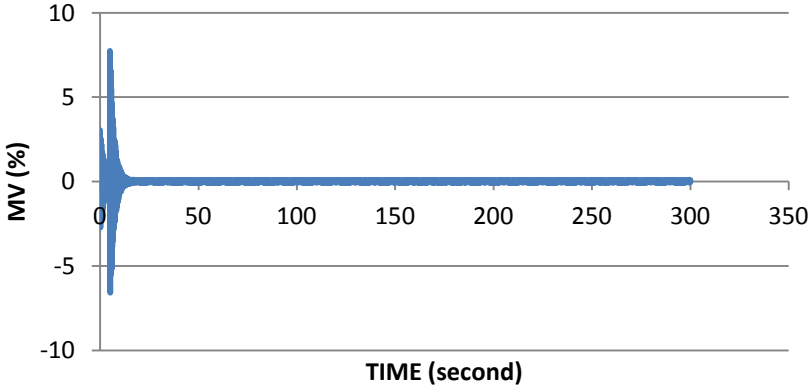
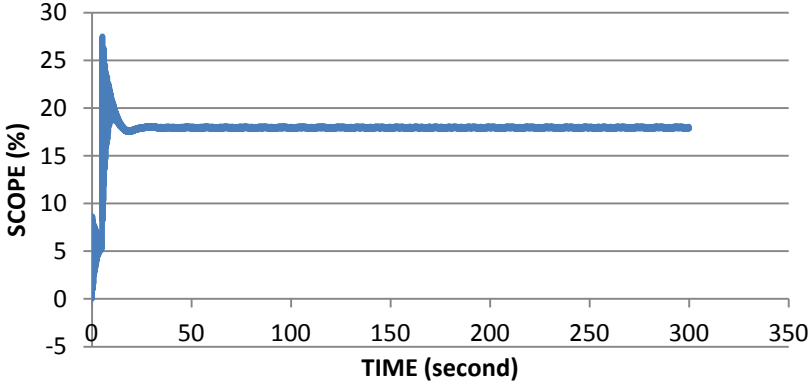
- Feedback Control



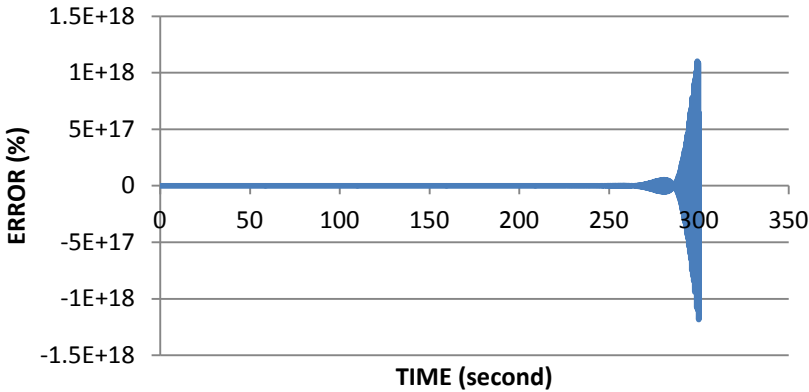
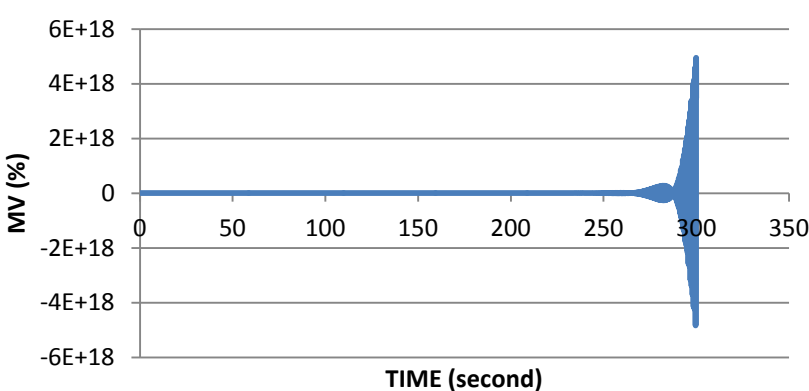
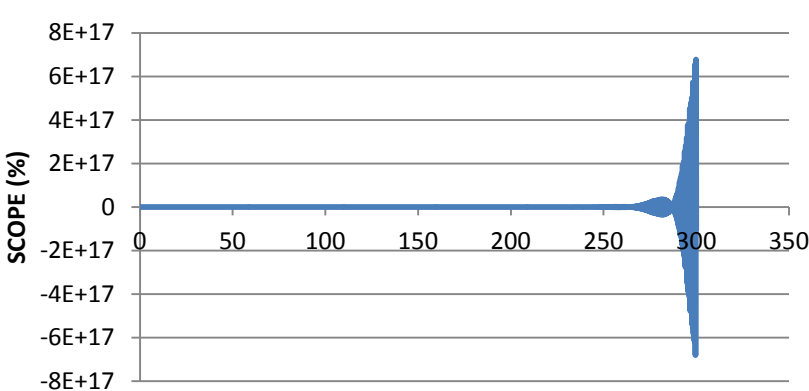
- Feedforward-feedback Control



- IMC Control

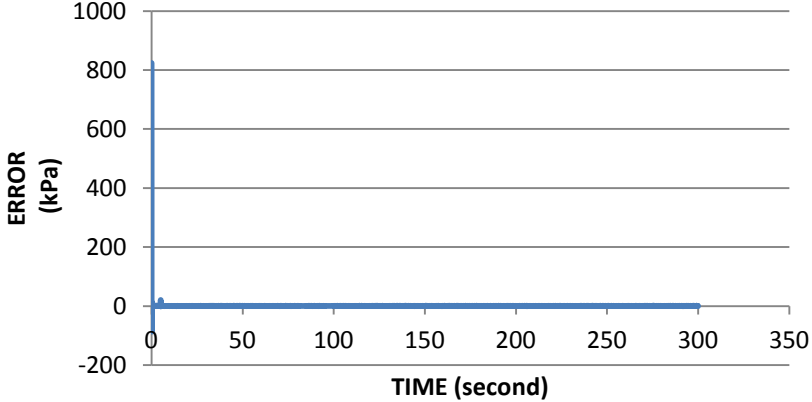
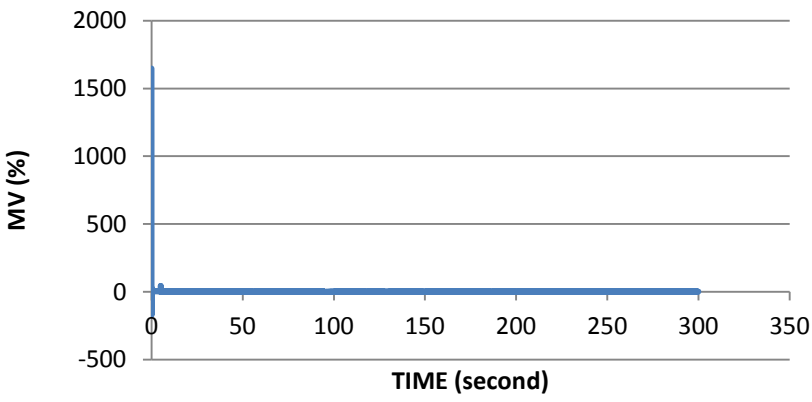
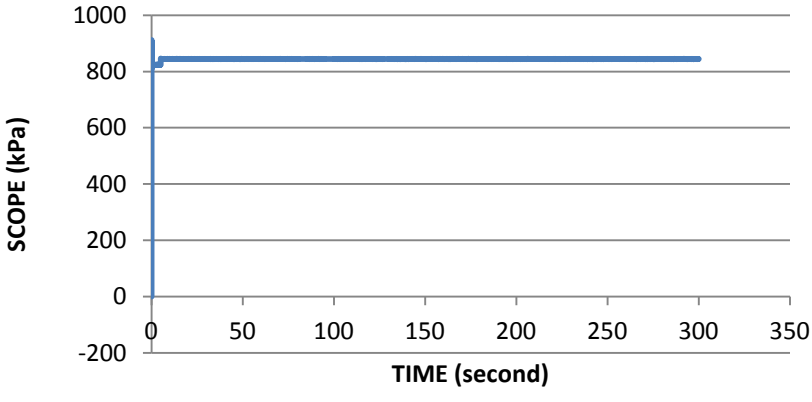
<p style="text-align: center;"><b>Error vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Area of error =</p> <p style="text-align: center;">2.8824</p> <p>Fluctuating at the beginning and then maintained stable.</p>
<p style="text-align: center;"><b>MV vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Fluctuating at the beginning and then maintained stable.</p>
<p style="text-align: center;"><b>Scope vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Fluctuating at the beginning and then maintained stable.</p>

- Smith Control

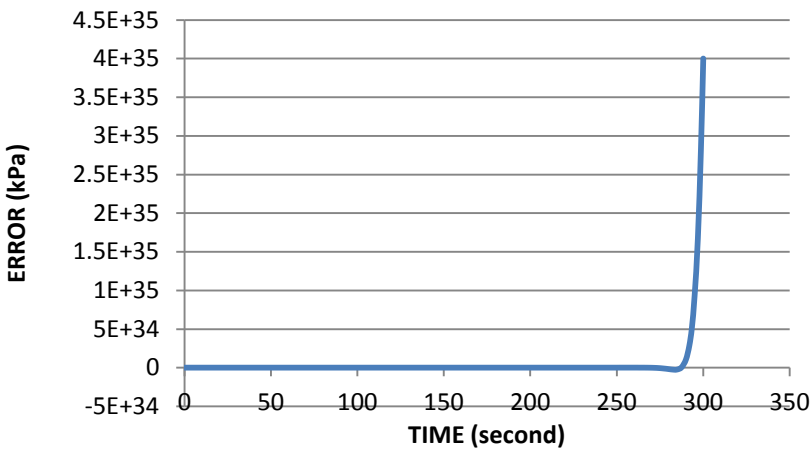
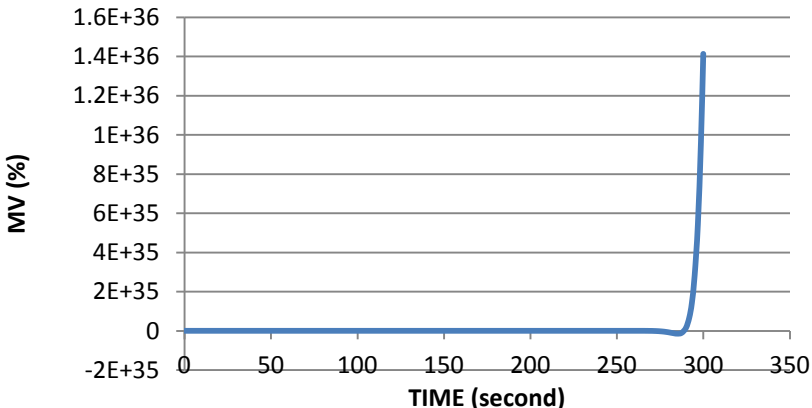
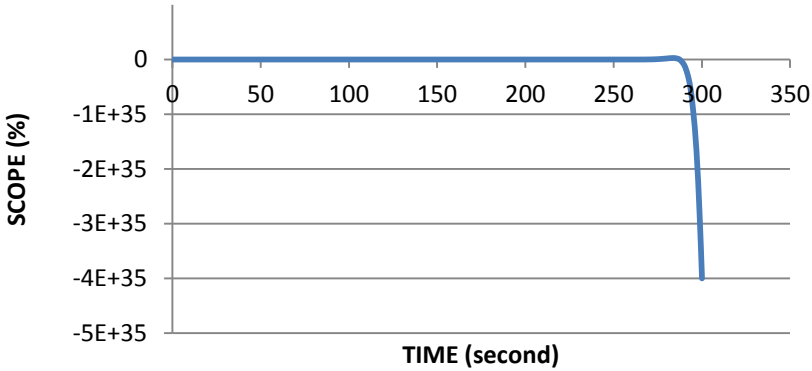
<h3>Error vs Time</h3>  <p>The plot shows the error percentage over time. The y-axis ranges from <math>-1.5 \times 10^{18}</math> to <math>1.5 \times 10^{18}</math> with major ticks every <math>5 \times 10^{17}</math>. The x-axis ranges from 0 to 350 seconds with major ticks every 50 seconds. The error is zero until approximately 280 seconds, where it begins to fluctuate, reaching a sharp negative peak of about <math>-1.2 \times 10^{18}</math> at 300 seconds before returning towards zero.</p>	<p>Area of error = <math>-8.02 \times 10^{16}</math></p> <p>Maintained stable at the beginning and then begin to fluctuate.</p>
<h3>MV vs Time</h3>  <p>The plot shows the manipulated variable (MV) percentage over time. The y-axis ranges from <math>-6 \times 10^{18}</math> to <math>6 \times 10^{18}</math> with major ticks every <math>2 \times 10^{18}</math>. The x-axis ranges from 0 to 350 seconds with major ticks every 50 seconds. The MV is zero until approximately 280 seconds, where it begins to fluctuate, reaching a sharp negative peak of about <math>-5 \times 10^{18}</math> at 300 seconds before returning towards zero.</p>	<p>Maintained stable at the beginning and then begin to fluctuate.</p>
<h3>Scope vs Time</h3>  <p>The plot shows the scope percentage over time. The y-axis ranges from <math>-8 \times 10^{17}</math> to <math>8 \times 10^{17}</math> with major ticks every <math>2 \times 10^{17}</math>. The x-axis ranges from 0 to 350 seconds with major ticks every 50 seconds. The scope is zero until approximately 280 seconds, where it begins to fluctuate, reaching a sharp negative peak of about <math>-7 \times 10^{17}</math> at 300 seconds before returning towards zero.</p>	<p>Maintained stable at the beginning and then begin to fluctuate.</p>

7.2.5 PRESSURE 1

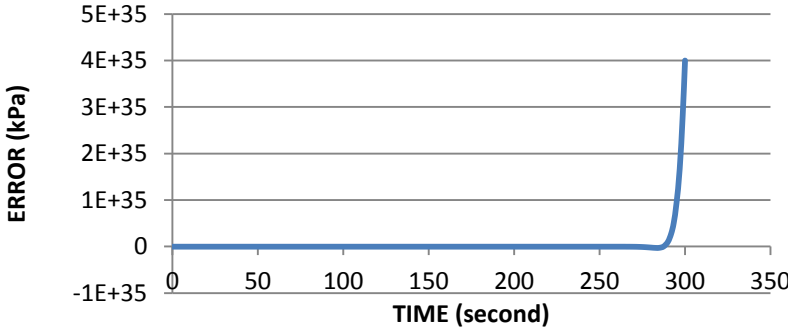
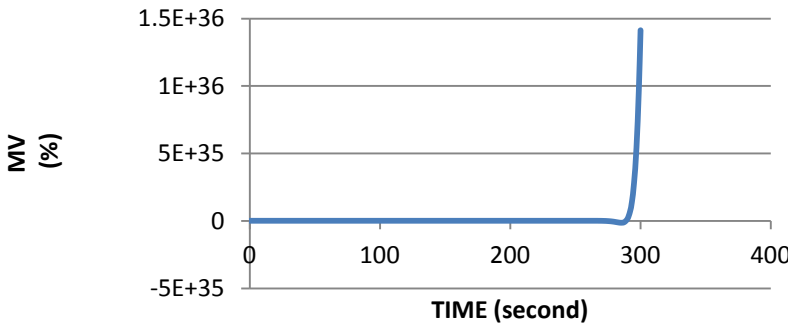
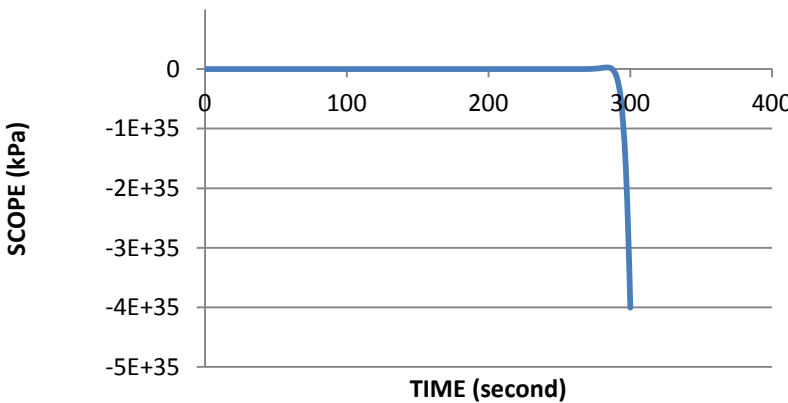
- Cascade Control

<div><p><b>Error vs Time</b></p><p>The graph shows Error (kPa) on the y-axis (ranging from -200 to 1000) and Time (second) on the x-axis (ranging from 0 to 350). A sharp spike in error occurs at the start, reaching approximately 800 kPa, and then stabilizes at zero.</p></div>	<div><p>Area of error =</p><p>7.2011</p><p>Unstable</p></div>
<div><p><b>MV vs Time</b></p><p>The graph shows MV (%) on the y-axis (ranging from -500 to 2000) and Time (second) on the x-axis (ranging from 0 to 350). A sharp spike in MV occurs at the start, reaching approximately 1700%, and then stabilizes at zero.</p></div>	<div><p>Unstable</p></div>
<div><p><b>SCOPE vs Time</b></p><p>The graph shows SCOPE (kPa) on the y-axis (ranging from -200 to 1000) and Time (second) on the x-axis (ranging from 0 to 350). A sharp spike in SCOPE occurs at the start, reaching approximately 900 kPa, and then stabilizes at approximately 850 kPa.</p></div>	<div><p>Unstable</p></div>

- Feedback Control

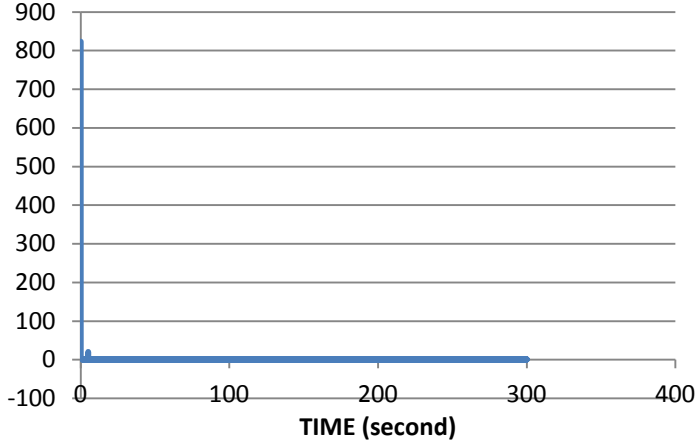
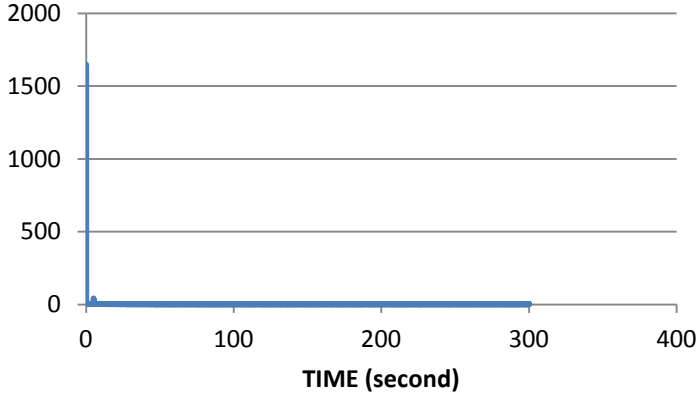
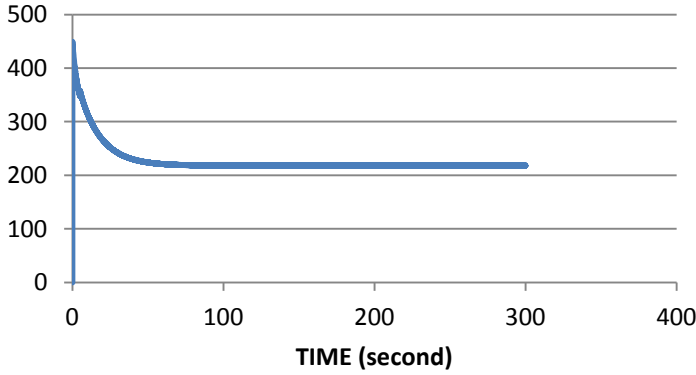
<h3>Error vs Time</h3>  <p>The graph shows the error signal over time. The y-axis is labeled 'ERROR (kPa)' and ranges from -5E+34 to 4.5E+35. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The error signal remains at zero until approximately 280 seconds, where it begins a sharp, nearly vertical rise, reaching a value of approximately 4E+35 kPa by 300 seconds.</p>	<p>area =</p> <p>1.31E+36</p> <p>Maintained stable and then the value increasing in short time.</p>
<h3>MV vs Time</h3>  <p>The graph shows the manipulated variable (MV) over time. The y-axis is labeled 'MV (%)' and ranges from -2E+35 to 1.6E+36. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The MV signal remains at zero until approximately 280 seconds, where it begins a sharp, nearly vertical rise, reaching a value of approximately 1.4E+36% by 300 seconds.</p>	<p>Maintained stable and then the value increasing in short time.</p>
<h3>Scope vs Time</h3>  <p>The graph shows the scope signal over time. The y-axis is labeled 'SCOPE (%)' and ranges from -5E+35 to 0. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The scope signal remains at zero until approximately 280 seconds, where it begins a sharp, nearly vertical drop, reaching a value of approximately -4E+35% by 300 seconds.</p>	<p>Maintained stable and then the value decreasing in short time.</p>

- Feedforward-feedback

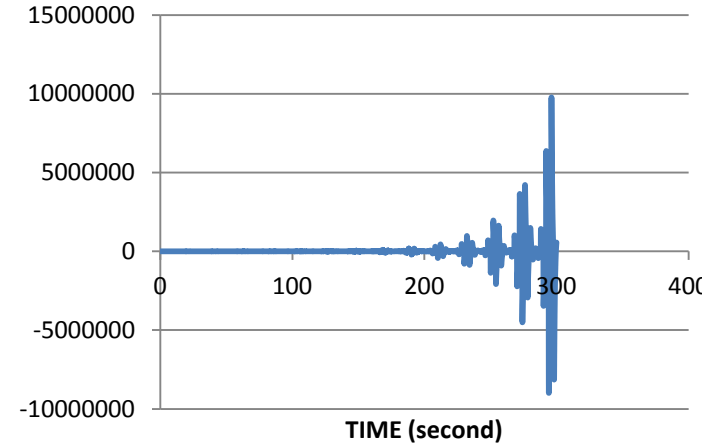
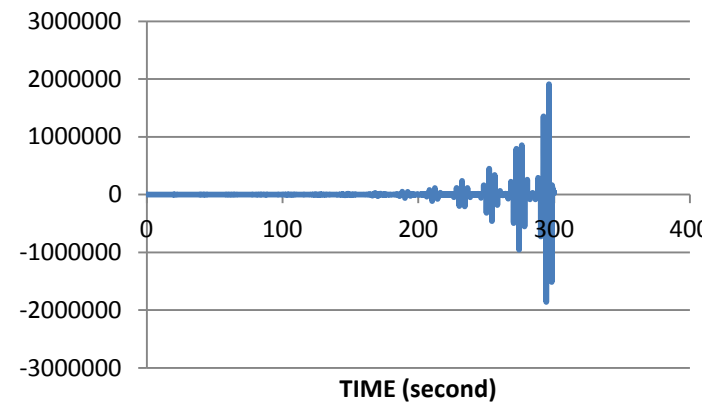
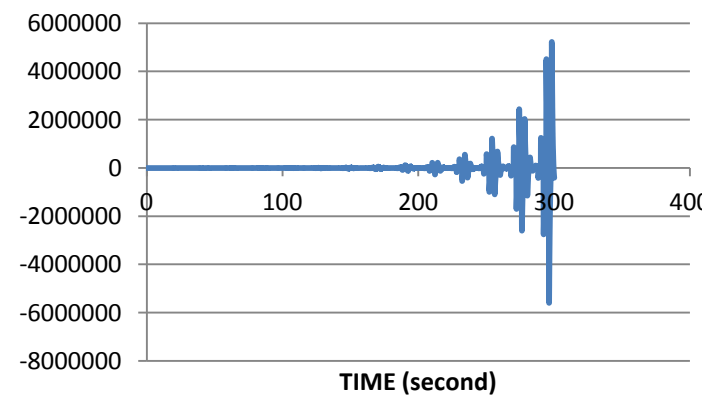
<h3>Error vs Time</h3>  <p>The graph shows the error signal over time. The y-axis is labeled 'ERROR (kPa)' and ranges from -1E+35 to 5E+35. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The error signal is zero until about 280 seconds, where it begins to rise exponentially, reaching 4E+35 kPa at 300 seconds.</p>	<p>Area of error =</p> <p>1.31E+36</p> <p>Maintained stable and then the value increasing in short time.</p>
<h3>MV vs Time</h3>  <p>The graph shows the manipulated variable (MV) over time. The y-axis is labeled 'MV (%)' and ranges from -5E+35 to 1.5E+36. The x-axis is labeled 'TIME (second)' and ranges from 0 to 400. The MV is zero until about 280 seconds, where it begins to rise sharply, reaching 1.5E+36% at 300 seconds.</p>	<p>Maintained stable and then the value increasing in short time.</p>
<h3>Scope vs Time</h3>  <p>The graph shows the scope signal over time. The y-axis is labeled 'SCOPE (kPa)' and ranges from -5E+35 to 0. The x-axis is labeled 'TIME (second)' and ranges from 0 to 400. The scope signal is zero until about 280 seconds, where it begins to drop sharply, reaching -4E+35 kPa at 300 seconds.</p>	<p>Maintained stable and then the value decreasing in short time.</p>



- IMC control

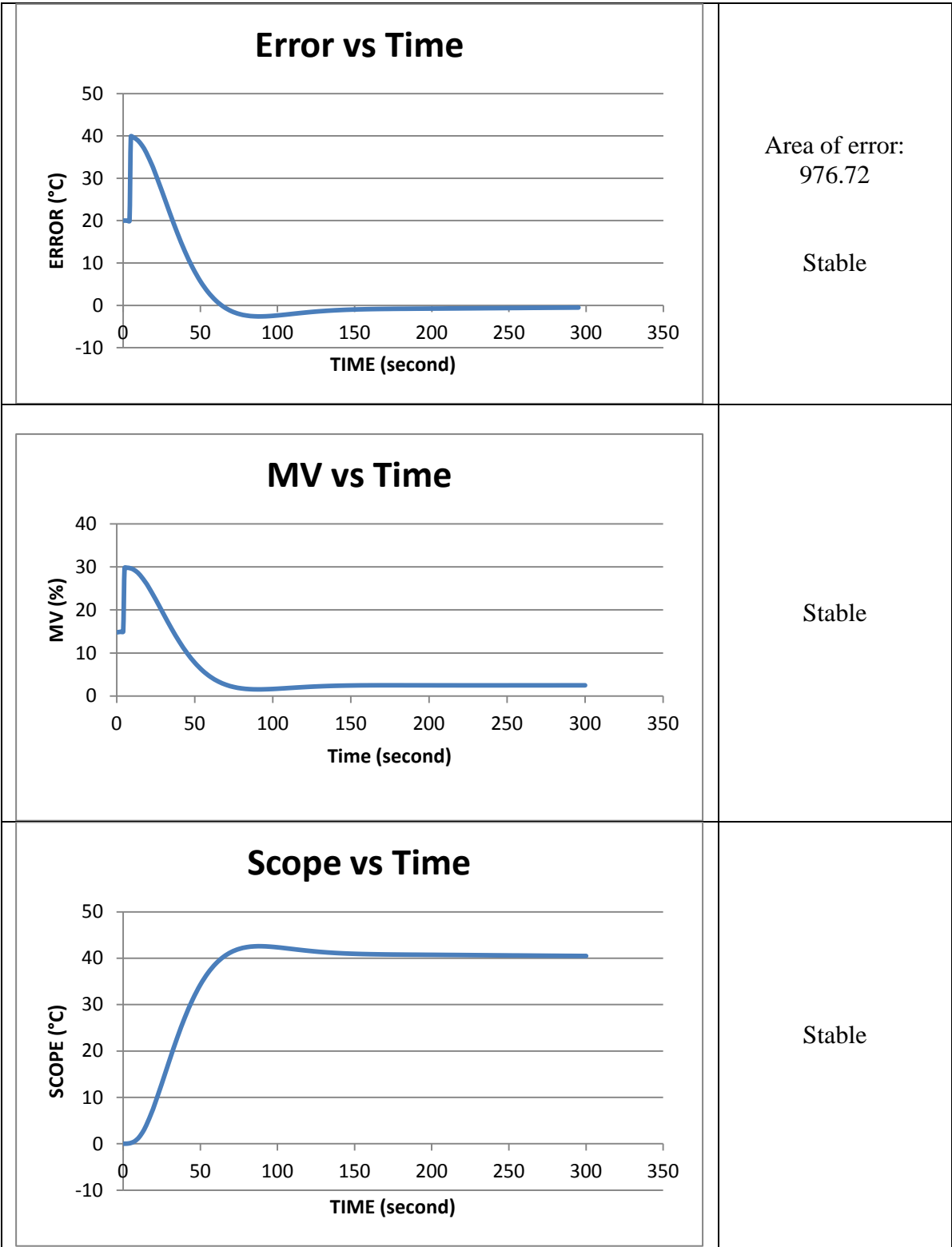
<p style="text-align: center;"><b>Error vs Time</b></p>  <p>The plot shows the error in kPa over time in seconds. The y-axis ranges from -100 to 900 kPa, and the x-axis ranges from 0 to 400 seconds. A sharp vertical spike occurs at t=0, reaching approximately 800 kPa, followed by a rapid decay to zero by t=20 seconds. The error remains at zero for the rest of the 300-second duration.</p>	<p>Area of error =</p> <p>110.9912</p> <p>Unstable</p>
<p style="text-align: center;"><b>MV vs Time</b></p>  <p>The plot shows the manipulated variable (MV) in percent over time in seconds. The y-axis ranges from 0 to 2000%, and the x-axis ranges from 0 to 400 seconds. A sharp vertical spike occurs at t=0, reaching approximately 1700%, followed by a rapid decay to zero by t=20 seconds. The MV remains at zero for the rest of the 300-second duration.</p>	<p>Unstable</p>
<p style="text-align: center;"><b>Scope vs Time</b></p>  <p>The plot shows the scope in kPa over time in seconds. The y-axis ranges from 0 to 500 kPa, and the x-axis ranges from 0 to 400 seconds. The scope starts at approximately 450 kPa at t=0 and decays smoothly, reaching a steady-state value of about 220 kPa by t=100 seconds. It remains constant at this level until t=300 seconds.</p>	<p>Stable</p>

- Smith Control

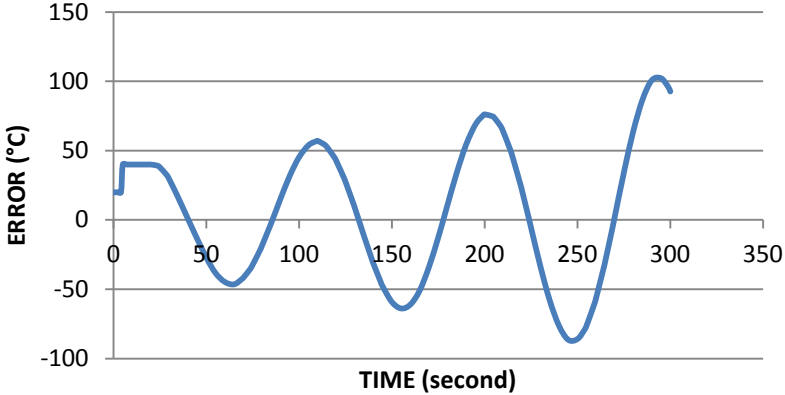
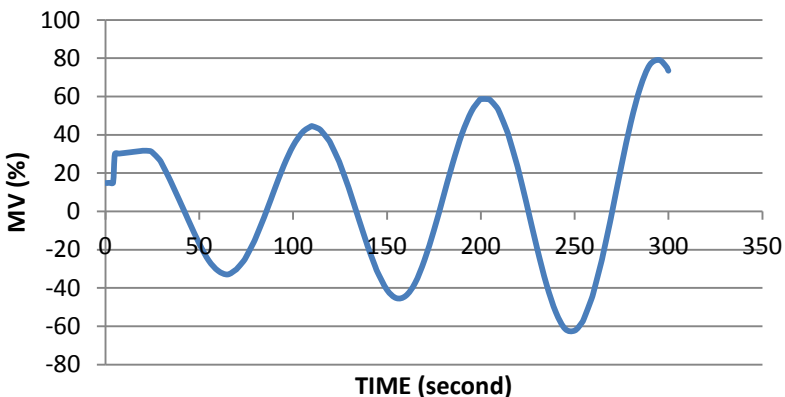
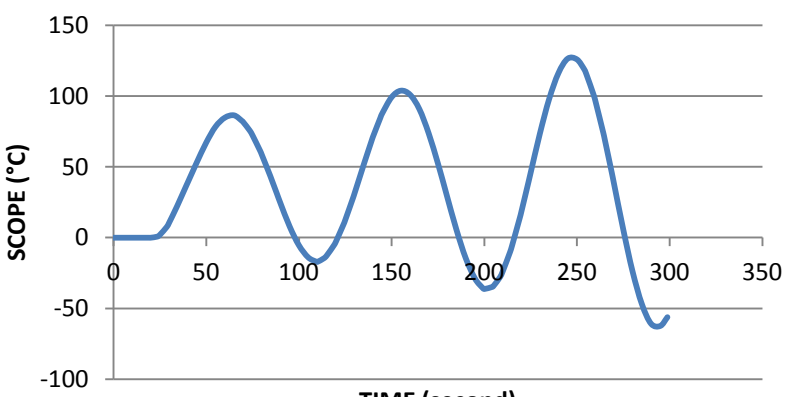
<p style="text-align: center;"><b>Error vs Time</b></p>  <p>ERROR (kPa)</p> <p>TIME (second)</p>	<p>Area of error =</p> <p>1.25E+06</p> <p>Fluctuating and unstable.</p>
<p style="text-align: center;"><b>MV vs Time</b></p>  <p>MV (%)</p> <p>TIME (second)</p>	<p>Fluctuating and unstable.</p>
<p style="text-align: center;"><b>Pressure vs Time</b></p>  <p>PRESSURE (kPa)</p> <p>TIME (second)</p>	<p>Fluctuating and unstable.</p>

**7.2.6 TEMPERATURE 5**

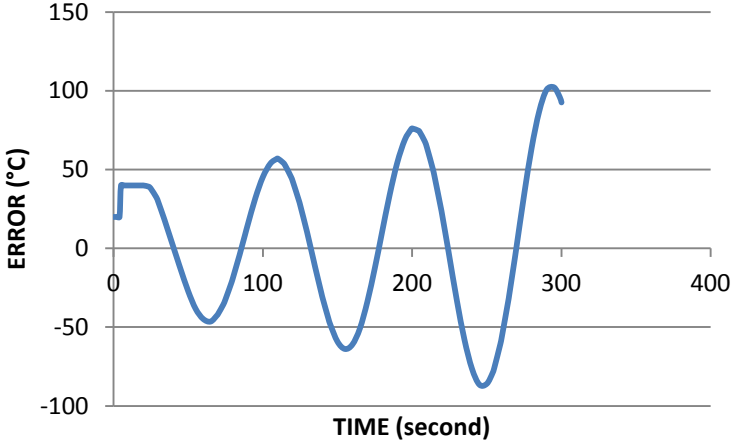
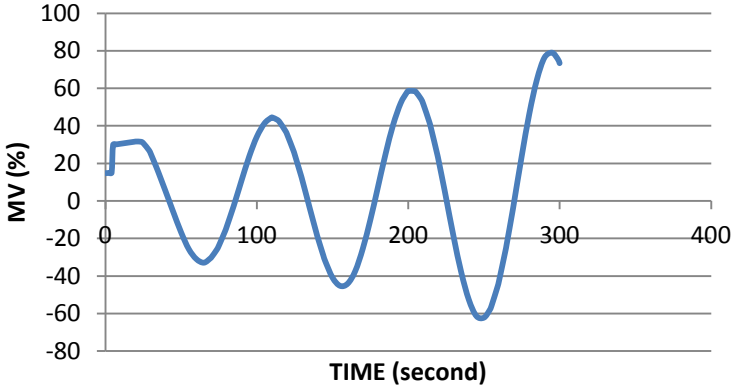
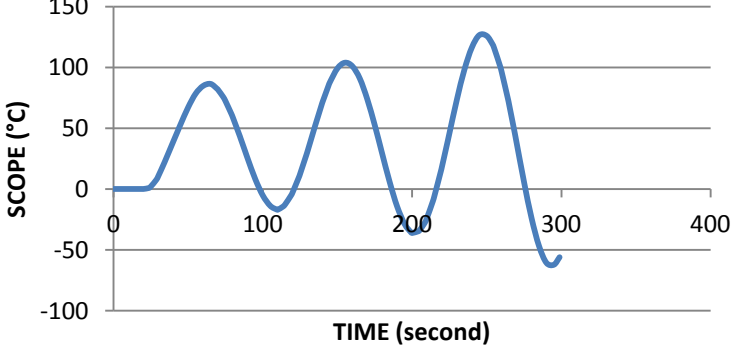
- Cascade Control



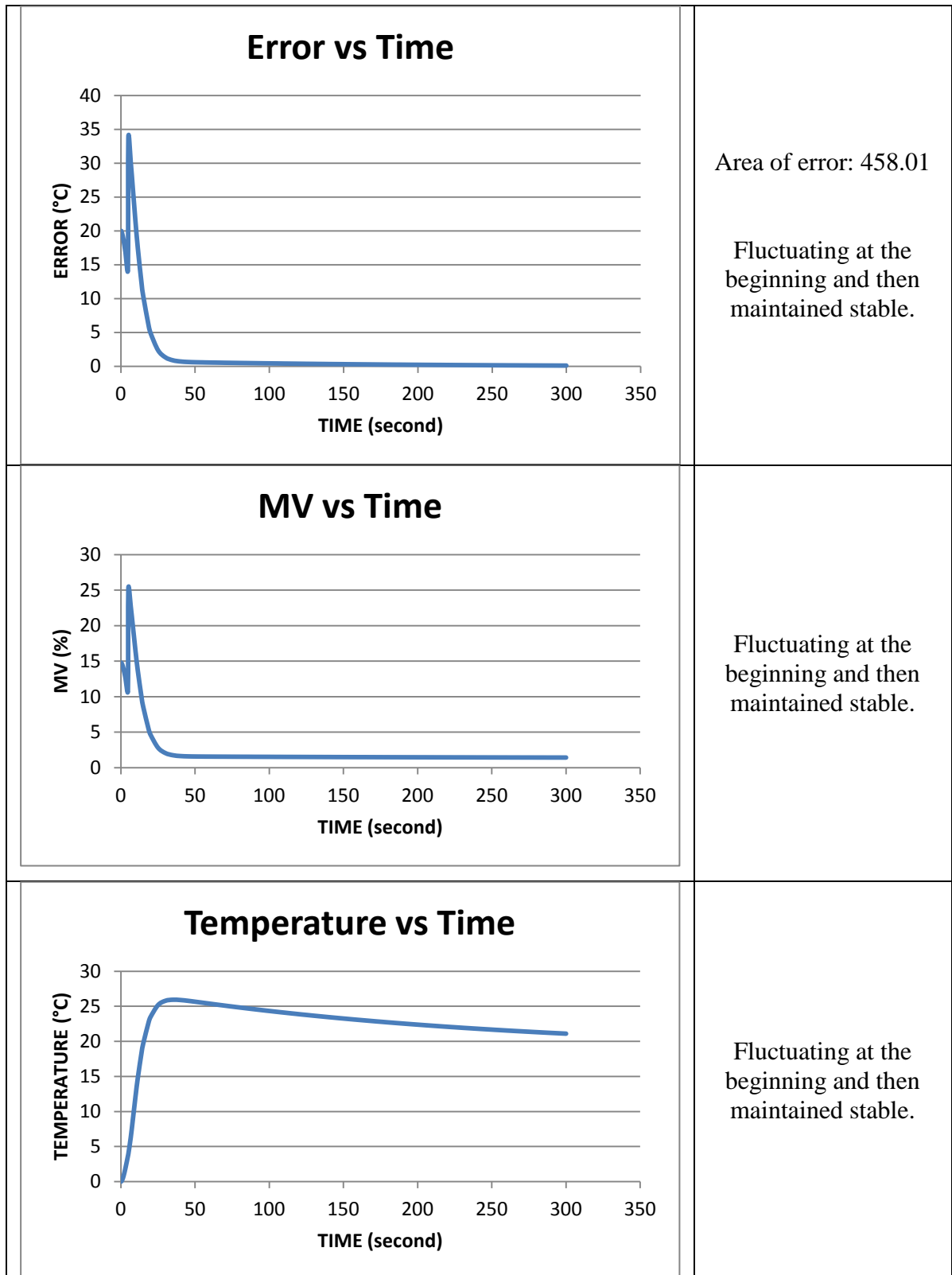
- Feedback Control

<h3>Error vs Time</h3>  <p>The graph shows the error signal over time. The y-axis is labeled 'ERROR (°C)' and ranges from -100 to 150. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The error starts at 0, jumps to 40 at t=10s, and then oscillates with decreasing amplitude, reaching approximately 100 at t=300s.</p>	<p>Area of error: 1633.75</p> <p>Fluctuating and Stable</p>
<h3>MV vs Time</h3>  <p>The graph shows the manipulated variable (MV) over time. The y-axis is labeled 'MV (%)' and ranges from -80 to 100. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The MV starts at 0, jumps to 30 at t=10s, and then oscillates with decreasing amplitude, reaching approximately 80 at t=300s.</p>	<p>Fluctuating and Stable</p>
<h3>Scope vs Time</h3>  <p>The graph shows the process variable (scope) over time. The y-axis is labeled 'SCOPE (°C)' and ranges from -100 to 150. The x-axis is labeled 'TIME (second)' and ranges from 0 to 350. The scope starts at 0 and oscillates with decreasing amplitude, reaching approximately 130 at t=300s.</p>	<p>Fluctuating and Stable</p>

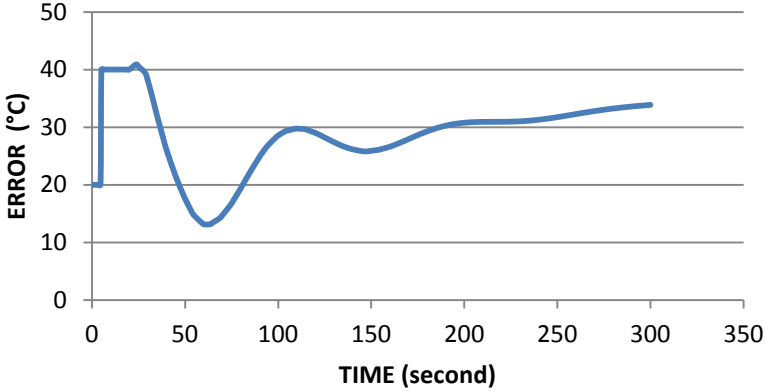
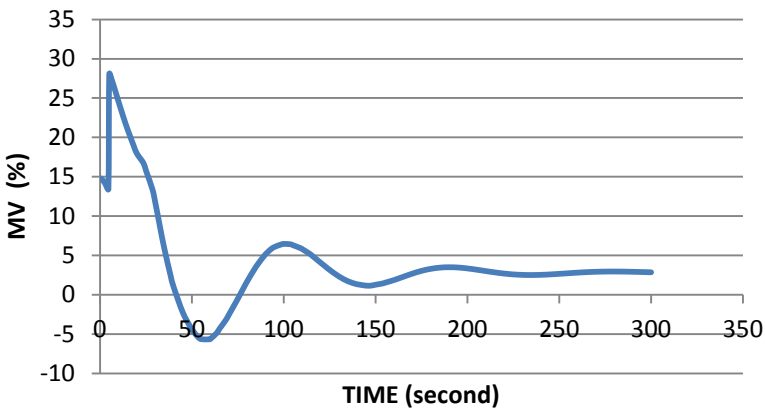
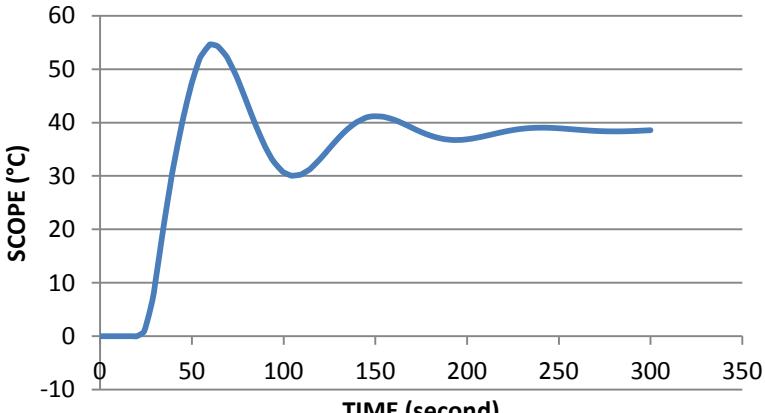
- Feedforward-feedback Control

<p style="text-align: center;"><b>Error vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Area of error :1633.75</p> <p>Fluctuating and Stable</p>
<p style="text-align: center;"><b>MV vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Fluctuating and Stable</p>
<p style="text-align: center;"><b>Scope vs Time</b></p>  <p style="text-align: center;">TIME (second)</p>	<p>Fluctuating and Stable</p>

- IMC Control



- Smith Control

<h3>Error vs Time</h3>  <p>Area of error: 8608.55</p> <p>Fluctuating at the beginning and then maintained stable</p>	
<h3>MV vs Time</h3>  <p>Fluctuating at the beginning and then maintained stable</p>	
<h3>Scope vs Time</h3>  <p>Fluctuating at the beginning and then maintained stable</p>	

